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India's technology opportunity: Transforming work, empowering people

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Preface

Millions of Indians hope for a better future, with well-paying jobs and a decent standard of living. To meet their aspirations, the country needs broad-based economic growth and more effective public services—delivered quickly. Technology can play an important role in raising productivity, efficiency, and innovation. Ironically, India's prowess in information technology is a defining element of its global brand, but so far, large parts of the country remain untouched by its power.

We believe that this can change and that technology can become an important driver of both economic growth and social development. A set of "empowering" technologies can dramatically reshape value chains and profit pools, bringing better lives to millions of Indians. We identify 12 technologies that are likely to be widely adopted in India over the next decade, with the potential to address the country's challenges and have massive impact on consumers, workers, and businesses. In this report, we describe more than 40 promising applications of these technologies across seven sectors of the economy. Collectively, these innovations can create immense economic value by 2025, provided supportive policies and scalable business models are in place. Our research brings these themes together, building on two recent MGI research efforts: *Disruptive technologies: Advances that will transform life, business, and the global economy* in 2013 and *From poverty to empowerment: India's imperative for jobs, growth, and services* in 2014.

This work was led by Anu Madgavkar, a senior fellow of MGI, along with Noshir Kaka, managing director of McKinsey in India; Pradeep Parameswaran, a McKinsey principal in New Delhi; James Manyika, a McKinsey and MGI director in San Francisco; and Jacques Bughin, a McKinsey director in Brussels. Sujit Chakrabarty, a principal with McKinsey's Business Technology Office, and Michael Chui, an MGI partner, made valuable contributions to the team. We offer sincere thanks to Gordon Orr, a McKinsey director in Shanghai, for his insights and guidance.

The research team, led by Tarun Garg and Ashwin Hasyagar, included Shambhavi A., Madhur Bansal, Pranay Bhatia, Rohan Chinchwadkar, Sonali Gupta, Parthiban Jayaprakash, Harsh Jhaveri, Mayank Kukreja, Rahul Mathew, Devi N., Meghana Rajeshwar, Vikas Siddheshwar, and Francesco Zerbato. MGI senior editor Geoffrey Lewis provided editorial support, and Marisa Carder and Samson Mathew provided graphic design support. We thank the MGI communications and operations team (Tim Beacom, Deadra Henderson, Julie Philpot, and Rebeca Robboy) and the McKinsey India External Communications team (Fatema Nulwala and Ava Sethna) for their contributions.

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Keshav Murugesh, Bhaskar Pramanik, Rishad Premji, Vijay Ratnaparke, BVR Mohan Reddy, Raman Roy, Shakti Sagar, Arun Seth, Arvind Thakur, Ashutosh Vaidya, Avinash Vashistha, and Jeffrey M. White. We especially thank NASSCOM officials Anupam Khanna, chief economist and director general; Sangeeta Gupta, senior vice president; and Rama Vedashree, vice president, e-governance and domestic IT, for their perspectives and expertise.

Several government leaders kindly contributed their extensive experience and shaped our understanding of issues: J. Satyanarayana, IT adviser to the government of Andhra Pradesh and former secretary, Department of Electronics and Information Technology, Government of India; Keshav Desiraju, secretary, Consumer Affairs Ministry and former secretary, Ministry of Health and Family Welfare, Government of India; B. K. Gairola, mission director, National eGovernance Plan, Government of India, and member secretary, National Innovation Council; and Rajendra Kumar, joint secretary, Department of Electronics and Information Technology, Government of India. We also gained valuable insights into e-governance from three World Bank officials: Randeep Sudan, practice manager for the ICT Sector Unit; Shashank Ojha, senior e-government specialist; and Siddhartha Raja, lead ICT policy specialist.

This work benefited from a host of interviews with technology and business innovators from various sectors. However, any references to specific companies in this report are from public sources. We gratefully acknowledge the contributions of Ajay Bakshi, managing director and CEO, Manipal Hospitals; Namita Dalmia, associate director, Central Square Foundation; Anand Deshpande, founder, chairman, and managing director, Persistent Systems; Vibhav Garg, head, health economics and government affairs, Boston Scientific; Arunabha Ghosh, chief executive officer of the Council on Energy, Environment, and Water; Myshkin Ingawale, founder, Biosense Technologies; Dr. Sujeet Jha, head of the Department of Endocrinology, Diabetes, and Obesity, Max Healthcare; Kanav Kahlol, team leader for Affordable Health Technologies, Public Health Foundation of India; Rajiv Lochan, trustee, IPK Trust; R. Mukundan, managing director, Tata Chemicals; Sridhar Rajagopalan, managing director, Educational Initiatives; Ramesh Ramanathan, chairman, and Santanu Mukherjee, senior vice president and head of strategic initiatives, both of Janalakshmi Financial Services; Saipriya Sarangan, vice president, The Skills Academy; Dr. Devi Shetty, chairman and founder, Narayana Health; and Shrikumar Suryanarayan, chairman, Sea6 Energy.

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We deeply appreciate the expertise contributed by many McKinsey colleagues across sector and functional practices. For overall technology insights, we benefited from the experience of Driek Desmet, Chandra Gnanasambandan, Malcolm Gomes, and Siddharth Gopalakrishnan. For financial services, we were guided by Renny Thomas and Ananya Tripathi. For the education sector, we drew on the expertise of Hemant Joshi, Shirish Sankhe, Ramdoss Seetharaman, and Ramya Venkataraman. Implications for the health-care sector were shaped by Palash Mitra, Ankur Puri, and Mandar Vaidya. For agriculture, we were assisted by Chandrika Gopalakrishnan, Saikiran Krishnamurthy, and Barnik Maitrad. Our insights on the impact of technology in the energy sector came from Amit Khera, Suhail Sameer, Kshitij Sanghi, and Vipul Tuli. For perspectives on technology in infrastructure, we called on Jim Banaszak, Rajat Gupta, Martin Joerrs, Thomas Netzer, Vijay Sarma, and Roland Villinger. Perspectives on e-governance came from Saket Jasoria and Martin Lundqvist. Kanaka Pattabiram and Kara Sprague gave us valuable insights on barriers to Internet adoption, drawing on their work for the upcoming McKinsey report *Offline and falling behind: Barriers to expanding Internet adoption*. MGI senior fellow Jeongmin Seong helped us with China-specific insights from MGI's July 2014 report, *China's digital transformation: The Internet's impact on productivity and growth*.

This report is part of our ongoing work about the impact of technology on national economies and on Indian economic empowerment. Our goal is to provide a fact base and insights about important technological developments that will help business leaders and policy makers develop appropriate strategies and responses. As with all of MGI's work, this report has not been sponsored in any way by any business, government, or other institution.

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India in 2025: potential impact of 12 empowering technologies

$550–1,000 billion
annual economic impact (20–30% of India's incremental GDP from 2012 to 2025)

400 million
additional people with access to quality health care

300 million
financially included people

14–24 million
workers could gain more years of education

15–60%
yield improvement for 22 million farmers due to precision agriculture

$50–95 billion
savings and productivity gain from energy technologies

$17–25 billion
economic value from intelligent transportation (roads and ports)

10 million
tech-enabled workers in health care, education, agriculture, citizen services, and financial services

19–29 million
non-farm workers who will need new job opportunities and skills

Contents

Executive summary	1
1. Twelve empowering technologies for India	13
2. Financial services	43
3. Education and skills	53
4. Health care	64
5. Agriculture and food	77
6. Energy	89
7. Infrastructure	99
8. Government services	113
9. Creating conditions for technologies to flourish	121
Bibliography	129

Executive summary

India has made progress towards its goal of bringing millions of people out of extreme poverty. However, despite these efforts, some 680 million Indians, or 56 percent of the population, still lack the basics of a minimum acceptable standard of living. What India needs now is a productivity- and efficiency-led transformation. If India can raise the productivity of its labour force and deliver basic services 50 to 100 percent more efficiently than in the past decade, half a billion people in India can be lifted to what we call the MGI "Empowerment Line", where they have the capacity to meet basic needs and maintain a decent standard of living, with access to health care, education, and other vital services.[1]

In this report we focus on a set of powerful technologies that can help raise productivity, improve efficiency across major sectors of the economy, and radically alter how services such as education and health care are delivered. By themselves—or even in combination—these technologies cannot bring about the full transformation that India needs. But these 12 technologies can have a disruptive impact on Indian businesses, government, and society. These "empowering" technologies have the potential to add economic value of $550 billion to $1 trillion per year in 2025, create millions of well-paying productive jobs (including ones for people with moderate levels of formal education), and help bring a decent standard of living to millions of Indians. Among our key findings:

- India is likely to experience very rapid diffusion and adoption of 12 general-purpose technologies and technology applications in the coming decade. The most potent of these, the mobile Internet, will likely reach 700 million to 900 million Indians by 2025. Along with cloud-based services, the automation of knowledge work, digital payments, and verifiable digital identity, the mobile Internet can provide the foundation for remote health care, adaptive learning, mobile agricultural extension services, and other innovative services. Beyond digital technologies, rapid advancements in energy (unconventional oil and gas, renewables, storage), genomics, advanced geographic information systems (GIS), and intelligent transportation and distribution can help India build a more stable power supply, raise productivity in farming, move goods and people more efficiently, and improve access to clean drinking water.

- When technology-based applications are used in combination, they can have transformative effects. For example, the mobile Internet could bring the knowledge of specialist physicians to community health workers using a combination of two other disruptive technologies: "automation of knowledge work" software residing in the cloud. Another powerful combination is using Internet of Things technology (tiny sensors that can be used for tracking),

1 For a detailed discussion on the Empowerment Line and the basket of basic consumption needs required for a minimum acceptable standard of living, see *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

the mobile Internet, and the cloud to monitor prescription drugs and stanch the flow of counterfeits. Internet of Things sensors in the water-supply infrastructure sending readings across the mobile Internet can detect flaws that could lead to contamination and consequent illness. No single technology application is as transformative as these combinations.

- Collectively, the 12 empowering technologies for India could contribute $550 billion to $1 trillion of economic impact per year in India in 2025. This is an estimate of the value created by additional productivity, savings of time and cost and energy, as well as benefits that these technologies could generate such as lives prolonged, carbon emissions avoided, and workers educated. The estimated impact is based on an analysis of more than 40 high-impact technology applications across seven sectors of the economy: financial services, education, health care, agriculture, energy, infrastructure, and government services.

- Much of the value created by empowering technologies likely will flow to consumers, including those in the poorer segments of the population. This "consumer surplus" would arise in a number of ways, including time savings, lower costs, greater convenience, and improved health. We estimate that empowering technologies can help some 400 million poor rural Indians gain access to improved health-care services (via remote health care and technology-enabled community health workers) and 24 million students gain four to eight more years of additional education by 2025. India's people can also benefit from technology in government that can boost transparency, curb corruption, and make government programmes more effective, for example, by using mobile payments to reduce leakage in welfare benefits.

- Our broad estimates suggest that 19 million to 29 million workers (5 to 8 percent of India's non-farm labour force in 2025) could potentially be negatively affected by technology and would need new employment opportunities and skills training. Some 6 million to 8 million of these workers would be employed in routine clerical, customer service, and sales jobs that could be affected by advancements in machine learning and natural language interfaces (speech recognition) that make it possible for computers to take on work that had been thought to be beyond machines. An additional 13 million to 21 million jobs in manufacturing, trade, transport, and construction could be affected by technology applications. To create a workforce that can adapt to such shifts, India will need a radical overhaul of education and vocational training systems as well as investments in continuous learning.

- Opportunities will likely be created for millions of workers and entrepreneurs by empowering technologies. Up to 20 million small and medium-sized enterprises (SMEs) could gain access to digital business tools in the cloud at a fraction of the cost of running in-house information technology (IT). About 90 million farmers could raise their productivity with real-time market information and as many as 22 million through precision farming. Millions of workers with little formal education could become knowledge workers in community health care, education, banking, and agriculture. With a bit of training and equipped with tablet computers linked to powerful cloud-based knowledge applications, they could make rudimentary diagnoses, teach lessons, provide farm-extension services, or help illiterate Indians conduct financial transactions.

- Ubiquitous digital technology can help create a "nation of micro-entrepreneurs". The mobile Internet and the cloud make it possible for all sorts of small service providers—caregivers, food preparers, plumbers, and drivers, as well as financial planners, accountants, and other freelance professionals—to find customers and offer services in an online marketplace. Consumers would benefit from an explosion of choices, and talented suppliers could build strong local or national reputations. Indians can also use this type of platform to participate in the "sharing economy"—matching real-time demand with spare or underutilised capacity. Consumers could connect to share rides for daily commutes, rent a car, or arrange a last-minute place to stay. Online sharing has many business applications, too—locating spare office space, meeting rooms, or even manufacturing or storage capacity or unused delivery vans.

- Disruptive technologies also involve disruptive business models, which can undermine the advantages of incumbents. Traditional sources of strategic advantage, such as established brands, large networks of stores or branches, and even factories could become balance sheet liabilities in a world of digital commerce and virtual organisations. A new source of competitive advantage will likely be the ability to drive greater consumer surplus using disruptive technologies. Business processes will become increasingly data-driven, and the most valuable asset may be talent with superior skills in data analytics. In an extreme scenario, the core business of a bank in 2025 could become one of branding and risk management, with most traditional banking elements outsourced to technology utilities.

- Government plays a key role in enabling (or holding back) new technologies and applications. The explosive growth of mobile phone service, which is having an impact on economic growth, in India was accelerated by early government measures to liberalise the telecommunications market and pro-consumer policies that reduced costs. Similarly, the government can accelerate the build-out of the telecom infrastructure needed to bring the mobile Internet to rural areas, and support domestic manufacturing of the low-cost devices needed in the digital economy. To promote adoption of empowering technologies, the government can also encourage entrepreneurism and innovation. Recent policy announcements suggest this has become a priority for the government. Its Digital India initiative, announced in August 2014, emphasises that digital infrastructure (digital identity, mobile Internet, electronic bank accounts) should become a widespread utility for citizens. It also envisions access to cloud-enabled services on demand and cashless financial transactions. Previously the government had announced a Rs. 10,000 crore ($1.7 billion) fund for startups, a Rs. 7,000 crore ($1.2 billion) budget to fund smart cities projects, and Rs. 500 crore ($90 million) for the National Rural Internet and Technology Mission.

IDENTIFYING 12 TECHNOLOGIES THAT WILL MATTER TO INDIA

To identify empowering technologies for India, we start with the criteria used to select MGI's global disruptive dozen: a disruptive technology has to have the potential for rapid adoption within a set time frame (by 2025); its benefits and impact must be felt widely, affecting many people, institutions, products, and markets; and the technology must have significant economic impact.[2] For India, we apply a fourth criterion: the technology must have the potential to help address India's economic and social challenges.

The resulting list of 12 empowering technologies for India fall into three types: technologies that "digitise" life and work, smart physical systems, and technologies for rethinking energy (Exhibit E1). Our list includes four technologies that are not on the global list, but which have particular relevance in India: digital payments, verifiable digital identity, intelligent transportation and distribution, and advanced GIS. All the technologies on our list are likely to reach rapid adoption in the coming decade (Exhibit E2). A few other technologies—advanced robotics, autonomous vehicles, 3D printing, and advanced materials—are also potentially important for India, but we do not focus on them in this research.

Exhibit E1

Twelve technologies can empower India in the next decade

Digitising life and work	**Mobile Internet**	Inexpensive and increasingly capable mobile devices and Internet connectivity enable services to reach individuals and enterprises anywhere
	Cloud technology	Computing capacity, storage, and applications delivered as a service over a network or the Internet, often at substantially lower cost
	Automation of knowledge work	Intelligent software for unstructured analysis, capable of language interpretation and judgment-based tasks; potential to improve decision quality
	Digital payments	Widely accepted and reliable electronic payment systems that can bring millions of unbanked Indians out of the cash economy
	Verifiable digital identity	Digital identity that can be verified using simple methods, enabling secure delivery of payments and access to government services
Smart physical systems	**Internet of Things**	Networks of low-cost sensors and actuators to manage machines and objects, using continuous data collection and analysis
	Intelligent transportation and distribution	Digital services, used in conjunction with the Internet of Things, to increase efficiency and safety of transportation and distribution systems
	Advanced geographic information systems (GIS)	Systems that combine location data with other types of data to manage resources and physical activities across geographic spaces
	Next-generation genomics	Fast, low-cost gene sequencing and advanced genetic technologies to improve agricultural productivity, nutrition, and health care
Rethinking energy	**Advanced oil and gas exploration and recovery**	Techniques that make extraction of unconventional oil and gas (usually from shale) economical, potentially improving India's energy security
	Renewable energy	Generation of electricity from renewable sources to reduce harmful climate impact and bring power to remote areas not connected to the grid
	Advanced energy storage	Devices or systems for energy storage and management that reduce power outages, variability in supply, and distribution losses

SOURCE: McKinsey Global Institute analysis

2 *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

Exhibit E2

Potential adoption of 12 empowering technologies in India

	Metric	Current estimates	Realistic aspiration for 2025
Mobile internet	Mobile Internet penetration in India	~8–10%	50–60%
	Mobile Internet users in India	100–130 million	700–900 million
Cloud technology	Percent of SMEs with a Web presence	<10%	50–55%
	Number of SMEs that are potential cloud users	~2 million	~20 million
	Extent of cloud-based government services to citizens	Nascent	Virtually universal
Automation of knowledge work	Number of smartphone users (potential intelligent app users)	~60 million	700–900 million
	Nature of applications	Basic, such as online information and booking	Adaptive, across sectors such as agriculture, health, education
Digital payments	Number of retail electronic and card transactions per year	1.5 billion	12 billion
	Number of retail establishments accepting digital payments (% of total)	0.6 million (6%)	>6 million (>60%)
Verifiable digital identity	Share of India's population with Aadhaar unique identity	~50%	~100%
	Share of financial and non-financial transactions linked to verifiable digital identity	<1%	~100% for all transactions needing identity verification
Internet of Things	Number of connected devices globally	9 billion	>50 billion
	Potential number of connected devices in India	n/a	2–10 billion
Intelligent transportation and distribution	Penetration of smart grid technology in India	<1% of grid	60–80% of grid
	Number of cities in India with some form of smart transport	<5	At least 50 (all current Tier 1 and Tier 2 cities)
Advanced geographic information systems (GIS)	Scope of GIS assets in India	Basic satellite images of forests, ground-water, soil, minerals from multiple agencies	Integrated, up-to-date, easy-to-use maps overlaid with diverse geo-tagged data including 3D, under-ground, and crowdsourced data
	GIS-based applications in India	Used by a few state governments; few apps for citizens	Ubiquitous GIS apps for decision support by all segments
Next-generation genomics	Hectares under hybrid and genetically modified crops in India (% of total planted area)	18 million ha (9%)	40 million ha (20%)
	Medical therapies based on advanced genomics	Nascent	Personalised therapies for 0.5–1.5 million patients; prenatal screening of 5–10 million births
Advanced oil and gas exploration and recovery	Unconventional gas production	~10 billion cubic feet	~235 billion cubic feet
Renewable energy	Solar energy generating capacity (in gigawatts)	1.7 GW	43 GW
	% of total generating capacity from solar	0.7%	9%
Advanced energy storage	Storage cost per megawatt-hours of energy	~$300	~$80
	Storage applications	Only large users	Universal use

SOURCE: Internet and Mobile Association of India; Pyramid Research; MGI SME survey on Internet usage; Reserve Bank of India; Unique Identification Authority of India; Cisco; Planning Commission, Government of India; International Service for the Acquisition of Agri-biotech Applications; Ministry of Agriculture, Government of India; World Health Organization; McKinsey Global Institute analysis

POTENTIAL ECONOMIC IMPACT OF $550 BILLION TO $1 TRILLION IN 2025

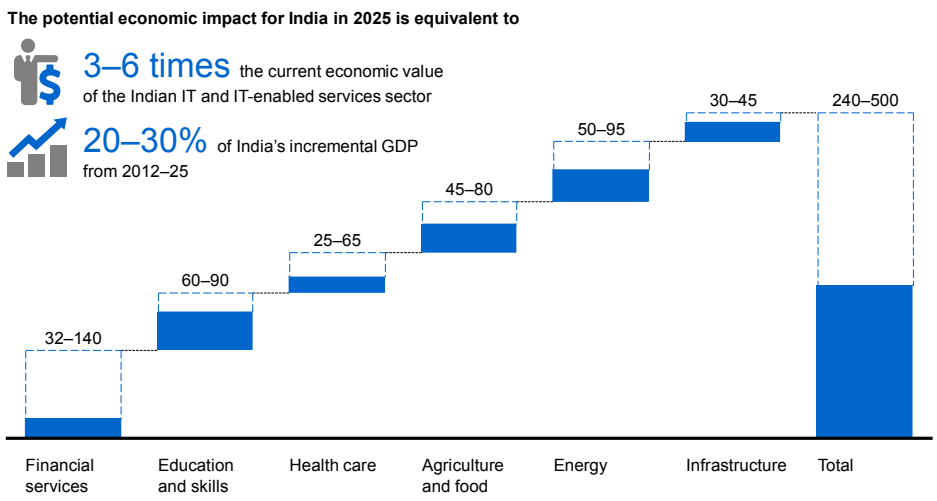
The 12 empowering technologies for India have the potential to create both economic and social value and can help India achieve its goals of rapid economic growth, greater social inclusion, and better governance by 2025. We estimate a potential economic impact of $550 billion to $1 trillion per year in 2025, led by applications in finance, energy, and education (Exhibit E3). This would be equivalent to 20 to 30 percent of India's GDP growth between 2012 and 2025, or three to six times the direct economic value contributed by the entire information technology sector in 2012. To understand the economic impact, we analyse a select set of applications across seven sectors: financial services, education, health care, agriculture, energy, infrastructure, and government services. The economic impact of these sized applications in 2025 could be $250 billion to $500 billion, or about 45 percent of the total impact.[3]

Exhibit E3

Economic impact of empowering technologies could be $550 billion to $1 trillion in 2025, with $240 billion to $500 billion from sized applications

Potential economic impact in 2025

Sized applications in six sectors ($ billion)



Notes on sizing

- Estimates of economic impact are not comprehensive and include potential direct impact of sized applications only.
- These estimates do not represent GDP or market size (revenue), but rather economic potential, including consumer surplus. Comparisons with GDP are only illustrative of the potential scope of impact.
- These estimates are not achievable through technology alone. They assume that enablers, such as training, incentives, and infrastructure, are put in place to capture the full potential value.
- Relative sizes of impact shown here cannot be considered a "ranking" because sizing is not comprehensive.
- We do not quantify the split or transfer of surplus among or across companies or consumers. Such transfers would depend on future competitive dynamics and business models.
- Estimates are not directly additive due to partially overlapping applications and/or value drivers.
- The estimates are not fully risk- or probability-adjusted.

NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

3 We do not size the economic impact of government services separately.

Beyond their economic impact, these technologies can help transform the lives of millions of Indians. By our estimates, they can help 200 million to 250 million Indians improve nutrition and raise incomes by receiving their full entitlements of subsidised food (using electronic payments or technology-enabled distribution to reduce leakage of benefits). About 90 million farmers in 2025 could improve their incomes through access to real-time market information. Technology-based teaching methods can improve school learning outcomes and thereby raise the productivity of some 24 million students who will enter the workforce by 2025, and help bring vocational training to 18 million to 33 million more Indians. An estimated 300 million Indians could achieve financial inclusion through technology-enabled services in 2025, and 400 million of India's poor could gain access to improved health-care services.

Realising this potential will not only require overcoming barriers such as limited telecom infrastructure, but it will also involve risks and costs that will need to be weighed. Widespread use of digital technologies raises questions about privacy and intellectual property protections. Businesses and individuals can be exposed to cybercrime. Advances in energy and genomics have implications for the environment. Regulators and policy makers will need to inform themselves about these issues, engage with the public and the business community, weigh the risks, and make their own judgments about necessary safeguards.

HOW 12 TECHNOLOGIES CREATE VALUE IN INDIA

To assess the potential contribution of empowering technologies to India's future, we conducted a bottom-up analysis of applications in seven sectors of the Indian economy that account for 45 percent of GDP and more than 60 percent of employment. In each of these sectors, we identify key challenges and the technologies that can help address them. For each sector, we rely on case examples and expert insights to refine the analysis and identify barriers to adoption and possible interventions.

- **Financial services.** India's banking sector has used technology to digitise business operations and to create new delivery models and services, such as online brokerage, mobile banking, and online insurance sales. Disruptive technologies now offer an opportunity to address persistent challenges such as lack of financial inclusion; just 36 percent of Indians have access to a bank account. Technology applications such as mobile payments can bring greater efficiencies; the government pays some $100 billion per year through paper-based channels. The applications we size could translate into economic value of $32 billion to $140 billion per year in 2025. The value arises from improved productivity and higher incomes of those using the services, and lower costs and reduced leakage in government transfers and payments. As many as 300 million Indians could gain access to banking services and could raise their incomes by 5 to 30 percent due to better access to credit and the ability to save and make remittances. Leakage of subsidies could be reduced by 8 to 10 percent.

- **Education and skills.** Learning outcomes in India's educational institutions are poor due to variable quality of teaching, and vocational training capacity is not adequate for the growing workforce. If these issues are not addressed, India could have far too many low-skill workers in 2025 than the labour market will require. Technology applications can improve the quality of teaching and raise vocational attainment. School performance can be improved through e-administration, digital identity-based attendance systems, and online teacher certification and training. Blended learning with MOOCs (massive open online courses) can bring high-quality courses to students, and learning simulations can boost hands-on training in nursing and other disciplines. We estimate an economic impact of $60 billion to $90 billion per year by 2025 from the higher productivity of more skilled workers. India could have about 24 million more high school- and college-educated workers and 18 million to 33 million more vocationally trained workers by 2025 due to use of digital technologies in the education sector.

- **Health care.** Based on international standards, India has about half the doctors, nurses, and health-care centres it needs for its population, and existing facilities are not geared to delivering optimal health outcomes. Disruptive technologies could transform delivery of public health services by 2025, extending care through remote health services (delivering expert consultations via the mobile Internet), digital tools that enable health-care workers with modest skills to carry out basic protocols, and low-cost diagnostic devices that work with smartphones. Using Internet of Things tracking systems to curb counterfeit drugs could be worth as much as $15 billion per year. The total value of empowering technologies in health care could be $25 billion to $65 billion per year in 2025. Of this, the largest share ($15 billion to $30 billion) could come from equipping health-care centres and health workers to bring services to some 400 million of India's poor.

- **Agriculture and food.** India's agriculture sector has made strides since the Green Revolution but still has immense potential to raise farm productivity and farm income. Hybrid and genetically modified crops, precision farming (using sensors and GIS-based soil, weather, and water data to guide farming decisions), and mobile Internet-based farm extension and market information services can help create more than half the $45 billion to $80 billion per year in additional value the sector could realise in 2025. The remainder would come from improvements to storage and distribution systems, which could cut postharvest losses and reforms to the public distribution system to reduce leakage, together saving as much as $32 million per year in 2025. These improvements could raise the income of as many as 100 million farmers and bring better nutrition to 300 million to 400 million consumers.

- **Energy.** Under current trends, by 2025, India could become one of the most energy-insecure countries in the world. Energy inclusion is also a major challenge: some 300 million people lack access to electricity. Globally disruptive energy technologies will have tremendous potential to improve sources of power in India as well: unconventional oil and gas, solar technology, and both grid and off-grid and offshore renewable energy sources like wind, solar, and seaweed biofuels. Advanced metering infrastructure, low-cost energy storage devices, and energy utilisation technologies can capture efficiencies along the value chain. Collectively, the technology applications we size in energy could have economic impact of $50 billion to $95 billion per year in 2025, including the impact of carbon emissions avoided. The largest potential impact would come from smart metering, which could save India $15 billion to $20 billion per year in 2025 in reduced transmission losses. Other large contributors would be energy-efficiency technologies for buildings and vehicles, which could save $15 billion worth of energy, and unconventional oil and gas, which might generate value of $10 billion per year in 2025.

- **Infrastructure.** India has a widely acknowledged infrastructure deficit that successive governments have attempted to address. Overcrowded roads, aging rail lines, and port systems using antiquated technology all slow the flow of goods and people and limit the growth potential of the economy; in India, logistics represent 14 percent of the cost of goods, compared with 6 to 8 percent globally. India needs new water and sanitation systems and has a housing gap of more than 18 million units. Infrastructure projects frequently come in late, over budget, and short of specifications. Use of radio frequency identification (RFID) tags and other tracking technologies can automate terminal and warehouse management, raising efficiency by 50 percent. Using sensors, water systems can cut leakage by 15 to 20 percent, helping reduce water shortages. And project-management systems and next-generation building technologies (extensive use of factory-made prefabricated parts, for example) can help India deliver ten million affordable homes by 2025. Together these infrastructure technologies can contribute $30 billion to $45 billion per year in value in 2025.

- **Government services.** Like other nations, India grapples with the challenge of making its government more effective and responsive to citizens. By our estimate, 50 percent of government spending on basic services does not translate into real benefits for people, and cumbersome government processes are an obstacle to investment and growth. We do not size the economic impact of e-government services, but their positive impact on competitiveness is well established. India has made a good start with its National e-Governance Plan, and it can take additional steps to capture the full potential over the next decade. Reengineering core government processes to simplify them and providing more integration of multiple services on technology platforms are essential next steps.

HOW TO NOURISH EMPOWERING TECHNOLOGIES

For these technologies to take root and have the level of impact we describe, India needs to create a supportive environment. In this report, we highlight a few broad-based enablers that the government could put in place to ensure that the benefits of empowering technologies can be felt across India.

- **Building physical infrastructure for the digital economy.** The cloud, the mobile Internet, the Internet of Things, digital payments, and other digital technologies depend on an affordable, reliable, and far-reaching Internet infrastructure. Universal, affordable Internet access is becoming a basic amenity of modern life and can be facilitated by fair and non-discriminatory regulatory policies. Accelerating implementation of the government's optical fibre backbone project will be critical in bringing Internet service to more citizens. There is also need to open up more spectrum for the massive growth in wireless data traffic. Cloud service providers need low-cost facilities with reliable electricity and access to telecom facilities.

- **Addressing barriers to technology adoption.** Lack of digital literacy is a significant barrier in India, and addressing this is essential to raise adoption rates for empowering technologies. India's many languages complicate the task of making technology accessible, as does the high rate of illiteracy. One approach may be to make systems as intuitive as the games and entertainment content that are so popular with smartphone users. Workers in government and private-sector organisations may also need to raise their technology skills to adopt advanced digital systems. Few companies or ministries have the in-house talent to conceptualise and create new applications and processes using digital systems. Setting up special-purpose government-sponsored technical organisations focused on training and capacity building for specific areas can help.

- **Providing effective policies, regulations, and standards.** For technologies to flourish in India, companies and consumers need a clear and predictable legal and regulatory environment. Policy approaches should be technology-agnostic and flexible; they should allow application and content developers to innovate with clear protections for copyrights and other intellectual property as well as data ownership. Citizens need protections to guard privacy and prevent cybercrime. In energy and genomics, best-practice regulatory frameworks address possible environmental, health, and security risks. Common standards for interoperability of data and devices can help expand the size of the market and encourage greater innovation. Finally, government can facilitate use of technologies in combinations (such as combining advanced GIS data with crop and soil data, and using advanced data analytics to provide advice to farmers via agricultural extension workers using the mobile Internet). This will require collaboration among many players: the Department of Space captures GIS images, and the Ministries of Planning, Agriculture, and Water collate data on soil conditions, water supplies, and other economic and natural resources, while farm extension workers are employed by the states.

- **Creating a vibrant innovation ecosystem and a mindset of "going for scale".** India can follow global best practices for creating a better environment for innovation. For example, Colombia created a one-stop shop and a central business registration database, reducing the average time needed to set up a new business from 57 days to three days. Apart from an overall business-friendly environment, startups can benefit from having a collection of well-defined problem statements, grand challenges, and idea pipelines. The Mahindra Spark the Rise challenge and Techpedia's online repository of 140,000 university technology projects are examples. As in the case of India's mobile telephony sector, scaling up for massive impact requires more than technology; large-scale innovation requires new approaches to pricing, manufacturing, and distribution, which can be facilitated by the right regulatory environment. Government procurement can also be used as a way to scale up new technologies. The government's Rs. 10,000 crore ($1.7 billion) fund for startups could be used to support promising technologies through purchases by ministries where appropriate.

- **Fostering more openness and transparency in government.** Open data can enable all sorts of applications, innovations, and new business models. India launched a government open data portal in 2013 that now provides access to more than 7,900 data sets. More departments and agencies could open up their data through a combination of mandates, incentives, and education to encourage more sharing. Timely and useful content sharing from the government also builds user engagement for online services. Indonesia launched the Public Participation Information System, which allowed citizens to monitor and verify the delivery of government services in real time, via a website or using SMS texting. The data can be used to improve resource allocation, for example to quickly fund the rebuilding of a fallen bridge. System data can also identify which mobile phone users who have registered with the site are close enough to investigate the problem and check whether it has been fixed.

- **Attracting private-sector R&D investment.** Research and development spending in India, at just 0.87 percent of GDP, is significantly lower than in Brazil (1.19 percent), China (1.70 percent), the United Kingdom (1.87 percent), the United States (2.79 percent), and South Korea (3.36 percent). India can attract more R&D investment and resources from global corporations and the domestic private sector. To do this, India would need to open its markets, remove barriers to doing business, and improve intellectual property protections. The government could consider establishing a dedicated public-private development fund for core technologies in infrastructure, energy, biotechnology, advanced genomics, and other high-priority fields. The government can also help fill some gaps in know-how by supporting a dedicated agency to work with the private sector to build expertise in areas such as data analytics and by establishing centres of excellence in solar R&D and renewable-energy management through public-private partnerships.

□ □ □

Empowering technologies can make a significant contribution to India's economic growth and its efforts to reduce poverty and enable more people to achieve a decent lifestyle, with greater economic opportunities and better access to water, sanitation, education, and health care. At the same time, powerful technological change carries risks for which India needs to prepare; millions of workers whose jobs include tasks that smart systems can perform might need to acquire new skills. The technologies we focus on in this research potentially will transform how Indians work, live, educate their children, travel, and engage with their government in the coming decade. They are only part of the solution to India's challenges; wider reforms and investments are also needed. But adopting these technologies can equip the nation to meet its larger challenges and help unleash the productivity- and efficiency-led transformation that India needs.

1. Twelve empowering technologies for India

In this report we look at the impact technology can have on the Indian economy and its people over the next ten to 15 years. This research builds on earlier work by the McKinsey Global Institute that identified 12 global technology areas that are rapidly evolving and have potential for widespread, disruptive impact on how people around the world live and work.[4] For India, we have identified 12 technologies based on their potential for disruptive impact as well as an additional requirement: they must have direct and large-scale potential to raise economic growth sustainably and enable millions of people to achieve a decent standard of living. In the following pages we discuss how we arrive at our list of 12 "empowering"' technologies for India and why we estimate that they can have $550 billion to $1 trillion per year in economic impact in 2025.

INDIA'S IMPERATIVE FOR A PRODUCTIVITY- AND EFFICIENCY-LED TRANSFORMATION

Since its economic reforms in the early 1990s, India has been making gradual progress towards the goal of eliminating poverty. The official poverty rate dropped from 45 percent in 1994 to 37 percent in 2005 (even as the total number of people living below the government's poverty line remained static at about 400 million). From 2005 to 2012, progress accelerated: as India's GDP grew by 8.5 percent per year, the share of the population living below the official poverty line fell from 37 percent to 22 percent, and the number of people living in poverty fell by about 137 million.[5]

Nevertheless, India's progress has been slower than that of China, which reduced the number of its people who were in extreme poverty by 497 million from 1994 to 2010.[6] Moreover, millions of Indians who have risen above the official poverty threshold continue to struggle for basic security and dignity. MGI's research indicates that in 2012 some 680 million Indians, or 56 percent of the population, lived below the MGI Empowerment Line, unable to fully meet basic needs for food, water, energy, sanitation, housing, health care, education, and social security.[7]

4 *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

5 Planning Commission of India.

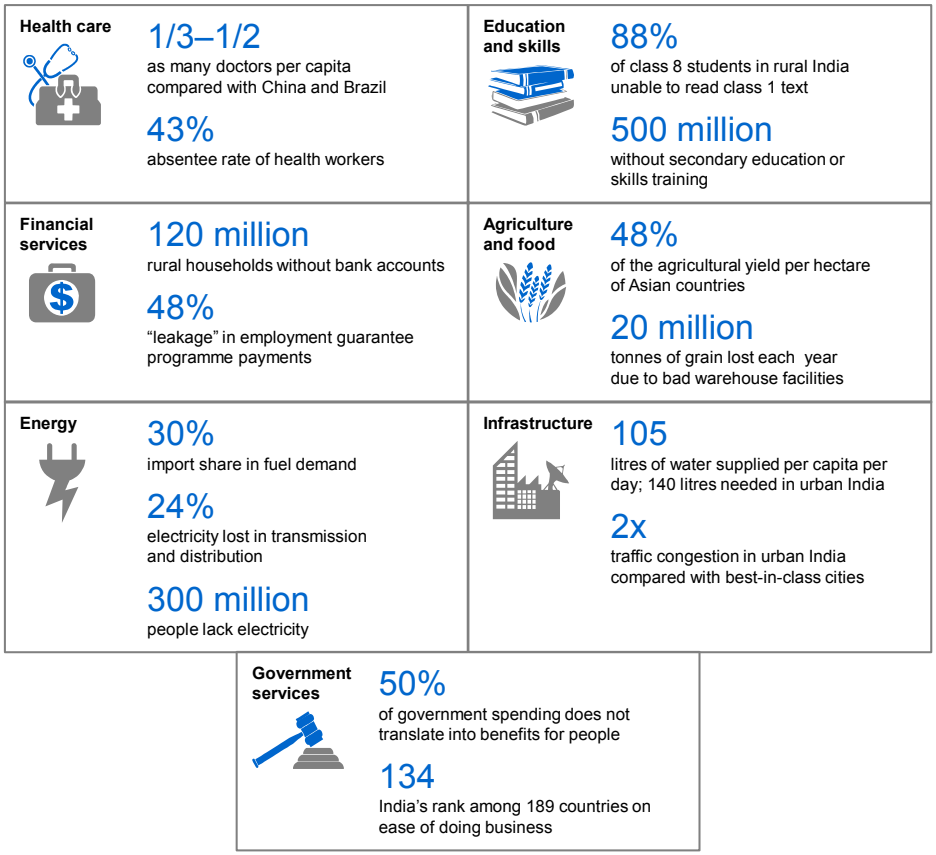
6 Defined as those living below the World Bank $1.25-a-day line (in 2005 prices).

7 For more about the empowerment concept, see *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

Poverty reduction would have been faster if India's economic growth had been more broad-based. However, growth in per capita income has been held back by slow progress in productivity due to the slow pace of non-farm job creation and a high share of informal and sub-scale enterprises. India's weak infrastructure, administrative barriers, and skills shortage have contributed to the problem. Meanwhile, public spending on basic services, such as education, health care, and subsidised food, has not been sufficient for poverty reduction. India has underinvested in such critical areas as health care—spending on public health services is just 1 percent of GDP, compared with more than 4 percent in Brazil and South Africa.[8] Delivery of other vital services has been inefficient, with only half of what is spent actually reaching the people either because programmes are ineffective or because funds "leak" before they reach intended beneficiaries. Exhibit 1 highlights the continuing challenges faced by India across many of these dimensions.

Exhibit 1

India's challenges include low productivity and inadequate access to basic services


Health care
1/3–1/2
as many doctors per capita compared with China and Brazil
43%
absentee rate of health workers
Education and skills
88%
of class 8 students in rural India unable to read class 1 text
500 million
without secondary education or skills training
Financial services
120 million
rural households without bank accounts
48%
"leakage" in employment guarantee programme payments
Agriculture and food
48%
of the agricultural yield per hectare of Asian countries
20 million
tonnes of grain lost each year due to bad warehouse facilities
Energy
30%
import share in fuel demand
24%
electricity lost in transmission and distribution
300 million
people lack electricity
Infrastructure
105
litres of water supplied per capita per day; 140 litres needed in urban India
2x
traffic congestion in urban India compared with best-in-class cities
Government services
50%
of government spending does not translate into benefits for people
134
India's rank among 189 countries on ease of doing business

SOURCE: World Health Statistics 2011; Jishnu Das et al., "In urban and rural India, a standardised patient study showed low levels of provider training and huge quality gaps", *Health Affairs*, volume 31, number 12, December 2012; *Annual status of education report (rural) 2012*, ASER Centre, January 2013; Reserve Bank of India; *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014; UN Food and Agriculture Organization; *India: Towards energy independence 2030,* McKinsey & Company, January 2014; Central Statistics Office, Energy Statistics; *World energy outlook 2013*, International Energy Agency, November 2013; *India's urban awakening: Building inclusive cities, sustaining economic growth*, McKinsey Global Institute, April 2010; World Bank; McKinsey Global Institute analysis

8 *World Health Statistics, 2011*, World Health Organization.

Looking ahead, India can do better to address its people's aspirations for a decent life. MGI research indicates that India can follow a path that would leave 100 million Indians, or just 7 percent of the population, below the Empowerment Line by 2022. This would require 50 percent faster growth in non-farm job creation, about twice the historical productivity growth rate in agriculture, and a 50 percent improvement in the efficiency of delivering public services. Given India's vastness and complexity, the magnitude of this challenge cannot be overemphasised. However, advances in technology present an opportunity for India to tackle long-standing barriers. As has been demonstrated in the telecom sector, broad-based technologies can achieve impact across a large swath of the economy and society (see Box 1, "Technology's broad-based impact in India: The case of mobile telecom").

Box 1. Technology's broad-based impact in India: The case of mobile telecom

Worldwide, general-purpose technologies (those that can be used repeatedly and are long-lasting and pervasive) have enabled major innovations, redefined value chains, and fostered transformative growth. Historical examples include the printing press and electric motors. A comparably transformative technology in India has been mobile telephony. The number of telephone subscribers in India grew from 28 million in 2000 to 938 million in 2014, driven by mobile telephony; mobile has achieved the most rapid and broad-based technology diffusion in India.[1]

Globally, investment in telecommunications infrastructure has yielded significant direct and indirect economic benefits as countries reach penetration levels approaching universal service, according to a 2001 study.[2] The study also found that, in developed economies, after penetration rates reach 40 percent, a 10 percent increase in telecommunications infrastructure investment was correlated with a 0.45 percent increase in GDP. In India, a 1.5 percentage point increase in GDP has been estimated for every ten percentage point increase in mobile penetration.[3]

The mobile revolution in India underscores not just the power of the technology itself, but also the essential role that enablers such as supportive government policies play in massive and broad-based technology impact. Mobile telephony took off in India following liberalisation of the sector in 1994 and adoption of proconsumer policies by an independent telecom regulator in 1999. The "calling-party-pays" rule, for example, made local incoming calls free and allowed millions of poor subscribers to use the "missed call" phenomenon to trigger action such as responding to a customer or fulfilling an order signalled by the missed call, making mobile service very useful. Liberalised import policies and the entry of global majors into domestic manufacturing created a competitive market for low-cost handsets.

Competition among carriers led to declining prices and massive innovation.[4] To reduce costs, telecom companies got together in 2007 to pool investments by building shared towers and other infrastructure through a common utility. They partnered with microfinance institutions to fund handset purchases in rural India and worked with consumer companies to reach millions of informal retail stores that top up prepaid cards. Today, an Indian consumer can buy a basic handset for less than Rs. 1,500 (about $25), pay one of the lowest tariff rates in the world, and buy talk time in micro-slivers of Rs. 10 (17 cents).

1 Telecom Regulatory Authority of India.

2 Lars-Hendrik Röller and Leonard Waverman, "Telecommunications infrastructure and economic development: A simultaneous approach", *American Economic Review*, volume 91, number 4, September 2001.

3 Rajat Kathuria and Mansi Kedia Jaju, *India: The impact of Internet*, ICRIER (Indian Council for Research on International Economic Relations), January 2012.

4 For more on innovations in the Indian telecom business models, see C. K. Prahalad and R. A. Mashelkar, "Innovation's Holy Grail", *Harvard Business Review*, July 2010.

IDENTIFYING TECHNOLOGIES THAT CAN EMPOWER INDIA

To select the top technologies that can have transformative impact on India in the coming decade, we drew on MGI's previous research that identified a set of 12 globally disruptive technologies.[9] We then applied an additional lens to see which technologies can help India fulfil its goals to achieve broad-based economic growth and bring decent living standards to its people. This led to four criteria:

- Does the technology have potential to address India's challenges and help fulfil the basic needs of its people?
- Does the technology have the rapidly falling costs and rising adoption rates that indicate widespread use and impact over the next decade?
- Can the technology affect a large number of workers, consumers, and businesses in India?
- Can the technology have significant economic impact for India in ten to 15 years?

To assess economic impact, we focus on seven sectors that have a critical role to play in fulfilling people's basic needs and driving economic growth: financial services, education and skills, health care, agriculture and food, energy, infrastructure, and government services. These sectors account for about 45 percent of GDP and more than 60 percent of employment. They face critical gaps and inefficiencies and have the potential to be disrupted by technology in the coming decade.

Exhibit 2 lists the 12 empowering technologies for India derived from this screening process. These are not the only technologies that could have empowering impact for India, but we have chosen to focus our analysis on these 12 based on our criteria. The technologies we focus on fall into three types: those that "digitise" life and work, smart physical systems, and technologies for "rethinking energy".

9 See *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013. The research selected 12 technologies out of 100 possible candidates drawn from academic journals, the business and technology press, analysis of published venture capital portfolios, and hundreds of interviews with relevant experts and thought leaders.

Exhibit 2
Twelve technologies can empower India in the next decade

Digitising life and work	**Mobile Internet**	Inexpensive and increasingly capable mobile devices and Internet connectivity enable services to reach individuals and enterprises anywhere
	Cloud technology	Computing capacity, storage, and applications delivered as a service over a network or the Internet, often at substantially lower cost
	Automation of knowledge work	Intelligent software for unstructured analysis, capable of language interpretation and judgment-based tasks; potential to improve decision quality
	Digital payments	Widely accepted and reliable electronic payment systems that can bring millions of unbanked Indians out of the cash economy
	Verifiable digital identity	Digital identity that can be verified using simple methods, enabling secure delivery of payments and access to government services
Smart physical systems	**Internet of Things**	Networks of low-cost sensors and actuators to manage machines and objects, using continuous data collection and analysis
	Intelligent transportation and distribution	Digital services, used in conjunction with the Internet of Things, to increase efficiency and safety of transportation and distribution systems
	Advanced geographic information systems (GIS)	Systems that combine location data with other types of data to manage resources and physical activities across geographic spaces
	Next-generation genomics	Fast, low-cost gene sequencing and advanced genetic technologies to improve agricultural productivity, nutrition, and health care
Rethinking energy	**Advanced oil and gas exploration and recovery**	Techniques that make extraction of unconventional oil and gas (usually from shale) economical, potentially improving India's energy security
	Renewable energy	Generation of electricity from renewable sources to reduce harmful climate impact and bring power to remote areas not connected to the grid
	Advanced energy storage	Devices or systems for energy storage and management that reduce power outages, variability in supply, and distribution losses

SOURCE: McKinsey Global Institute analysis

Four technologies on our list for India were not on the global list—digital payments, verifiable digital identity, intelligent transportation and distribution, and advanced GIS. These technologies are well dispersed in advanced economies, but they meet MGI's criteria for potential disruption in India because they are growing off a small base and their accelerating adoption will have transformative effects in the coming decade. Some technologies beyond this list could be important for India as well, but we did not study them in this research because they do not meet all our criteria (see Box 2, "Other technologies on the radar").

Box 2. Other technologies on the radar

Some technologies on MGI's global list did not make our final list of empowering technologies for India, but they may be more important in the longer term. They did not make our list because their economic and social impact in India in the coming decade could be less than that of others that we chose. However, they have relevant and important applications in select areas and should not be ignored.

- **Advanced robotics** will be used to automate a greater share of mechanised work in India but will be less relevant than in advanced economies for valuable applications such as human augmentation (robotic prosthetics, for example) or in services such as janitorial work and lawn care.
- **Advanced materials** such as graphene and carbon-based nanotubes could be used to produce ultra-efficient batteries, flexible and transparent displays, and filters that produce potable water. However, these technologies may not be available on a large scale within a decade.
- **3D printing** will have important applications in India—in medical implants and prosthetics, for example—but is less likely to become a significant force across the manufacturing sector in the next decade.
- **Autonomous and near-autonomous vehicle technology** for driverless cars and buses may find select applications in India in freight logistics, but it is not likely to be widely adopted for passenger vehicles or commercial transportation.

POTENTIAL SCALE OF EMPOWERING TECHNOLOGIES IN INDIA

Each technology on our list is rapidly dispersing in the world and in India and can affect a wide range of activities. The exact extent and pace of adoption is hard to predict, but we believe that all these technologies are likely to achieve levels of adoption that could lead to significant impact across sectors. Exhibit 3 summarises aspirations for adoption that India could set for 2025.

Exhibit 3
Potential adoption of 12 empowering technologies in India

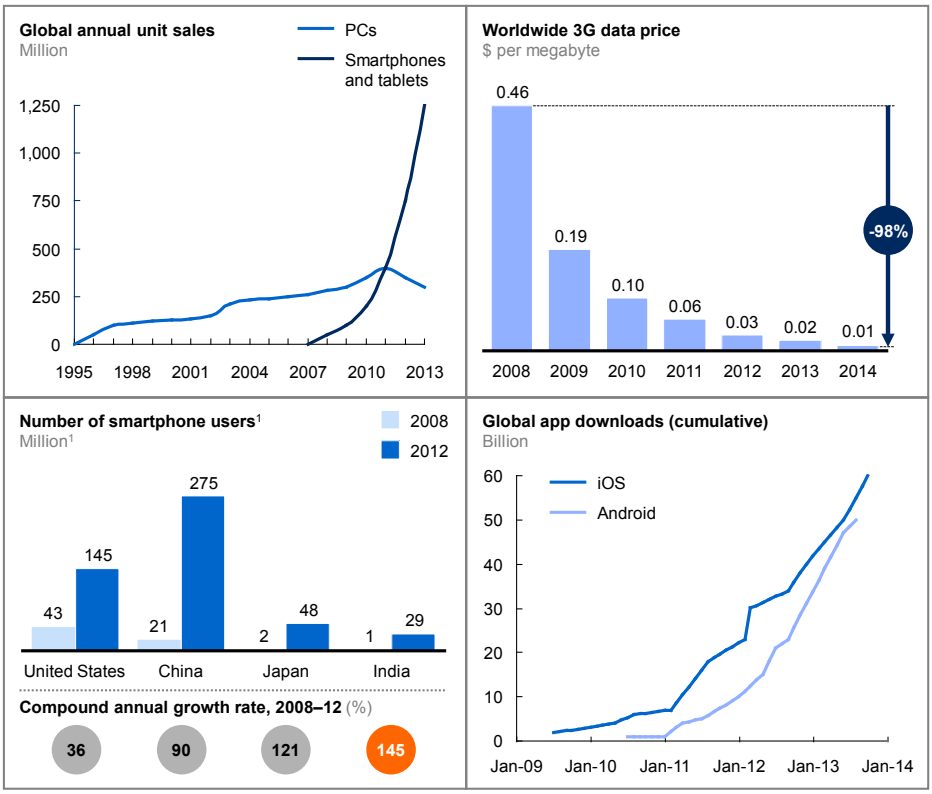
	Metric	Current estimates	Realistic aspiration for 2025
Mobile internet	Mobile Internet penetration in India	~8–10%	50–60%
	Mobile Internet users in India	100–130 million	700–900 million
Cloud technology	Percent of SMEs with a Web presence	<10%	50–55%
	Number of SMEs that are potential cloud users	~2 million	~20 million
	Extent of cloud-based government services to citizens	Nascent	Virtually universal
Automation of knowledge work	Number of smartphone users (potential intelligent app users)	~60 million	700–900 million
	Nature of applications	Basic, such as online information and booking	Adaptive, across sectors such as agriculture, health, education
Digital payments	Number of retail electronic and card transactions per year	1.5 billion	12 billion
	Number of retail establishments accepting digital payments (% of total)	0.6 million (6%)	>6 million (>60%)
Verifiable digital identity	Share of India's population with Aadhaar unique identity	~50%	~100%
	Share of financial and non-financial transactions linked to verifiable digital identity	<1%	~100% for all transactions needing identity verification
Internet of Things	Number of connected devices globally	9 billion	>50 billion
	Potential number of connected devices in India	n/a	2–10 billion
Intelligent transportation and distribution	Penetration of smart grid technology in India	<1% of grid	60–80% of grid
	Number of cities in India with some form of smart transport	<5	At least 50 (all current Tier 1 and Tier 2 cities)
Advanced geographic information systems (GIS)	Scope of GIS assets in India	Basic satellite images of forests, ground-water, soil, minerals from multiple agencies	Integrated, up-to-date, easy-to-use maps overlaid with diverse geo-tagged data including 3D, under-ground, and crowdsourced data
	GIS-based applications in India	Used by a few state governments; few apps for citizens	Ubiquitous GIS apps for decision support by all segments
Next-generation genomics	Hectares under hybrid and genetically modified crops in India (% of total planted area)	18 million ha (9%)	40 million ha (20%)
	Medical therapies based on advanced genomics	Nascent	Personalised therapies for 0.5–1.5 million patients; prenatal screening of 5–10 million births
Advanced oil and gas exploration and recovery	Unconventional gas production	~10 billion cubic feet	~235 billion cubic feet
Renewable energy	Solar energy generating capacity (in gigawatts)	1.7 GW	43 GW
	% of total generating capacity from solar	0.7%	9%
Advanced energy storage	Storage cost per megawatt-hours of energy	~$300	~$80
	Storage applications	Only large users	Universal use

SOURCE: Internet and Mobile Association of India; Pyramid Research; MGI SME survey on Internet usage; Reserve Bank of India; Unique Identification Authority of India; Cisco; Planning Commission, Government of India; International Service for the Acquisition of Agri-biotech Applications; Ministry of Agriculture, Government of India; World Health Organization; McKinsey Global Institute analysis

Digitising life and work

This group of technologies includes the mobile Internet, cloud storage, automation of knowledge work, digital payments, and verifiable digital identity. They are being adopted at a rapid pace in India (Exhibits 4 and 5) and will have growing impact between now and 2025.

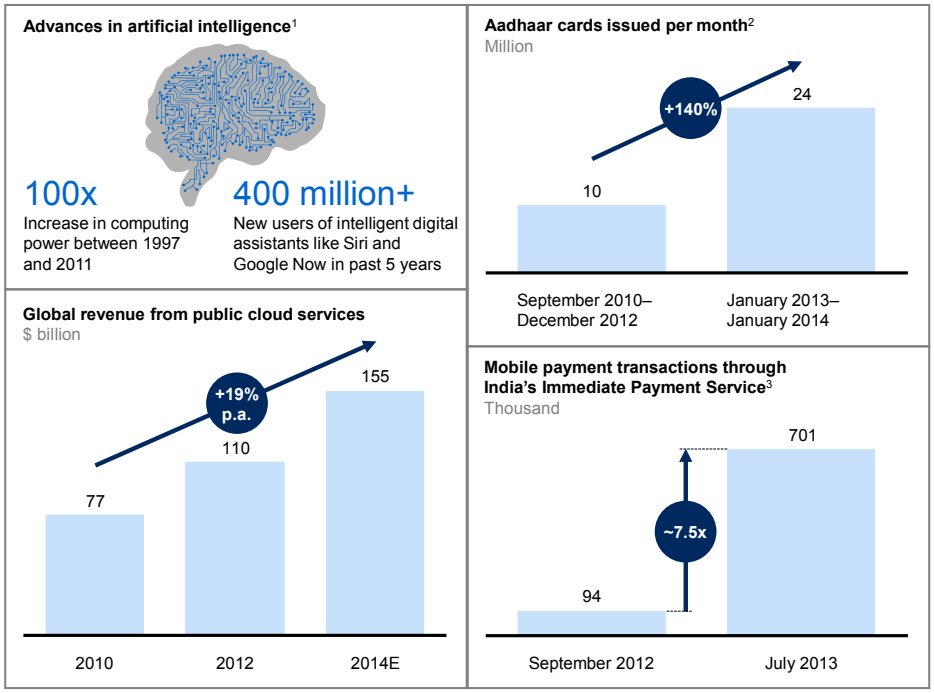
Exhibit 4
Exponential growth in mobile Internet services, smartphones, and apps



SOURCE: Benedict Evans, *Mobile is eating the world*, November 2013; Bharti Airtel; RComm; McKinsey Global Institute analysis

Exhibit 5

Rise in adoption of cloud, automation of knowledge work, digital payments, and verifiable digital identity



1 Example: increase in processing power of IBM Watson/Deep Blue supercomputer between 1997 and 2011.
2 Aadhaar is a unique identity card issued by the government of India.
3 Immediate Payment Service is offered by National Payments Corporation of India for mobile payments.

SOURCE: Gartner estimates (2013); *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013; *M-banking and m-payments: The next frontier*, Deloitte, 2013; Press Information Bureau, Government of India; Planning Commission, Government of India; McKinsey Global Institute analysis

Mobile Internet

The mobile Internet is the technology with the greatest potential to have disruptive economic impact globally and in India. It can help millions gain access to affordable health care, quality education, basic financial services, government services, and the information, know-how, and market access to work more productively.

Globally, the International Telecommunication Union estimates that there are 2.5 billion Internet users today. Some 1.6 billion have been added since 2004. Most of the growth is coming from Asia, which now has 45 percent of the world's Internet users, many of whom have only ever accessed the Internet via mobile phone service. By mid-2014, an estimated 185 million Indians were using mobile phones to access the Internet, from almost none in 2005.[10] Indians have about 100 million active Facebook accounts, and WhatsApp, a mobile messaging app, is used by more than 50 million Indians.[11] China's rapid adoption of smartphones has helped to bring down prices globally, and recently India has become one of the fastest-growing smartphone markets in the world. Google announced a tie-up with three Indian handset companies to manufacture a smartphone that would

10 Internet and Mobile Association of India.

11 Shelley Singh, "After 100 million users in India, Facebook aims at 1 billion", *Economic Times*, April 9, 2014; Rajat Agrawal, "WhatsApp crosses 50 million monthly active users in India, ties up with Airtel for special data plans", BGR, May 10, 2014.

be sold for less than $100. The rollout of 4G services by major Indian telecom providers and falling prices for calling plans should continue to drive adoption. We expect that mobile Internet penetration will reach 700 million to 900 million Indians by 2025 (about 50 to 60 percent of the total population, up from 8 to 10 percent currently).

Cloud technology

The cloud has evolved from a form of remote computing and data storage to a platform for mobile Internet services—everything from email to providing the processing power to translate the user's spoken commands into computer instructions (as in Apple's Siri or Google Now). In India, the cloud has particular potential for bringing low-cost IT services to businesses that have not computerised operations because they lack the money and technical know-how to implement IT systems in-house.

On-demand IT services could help modernise thousands of small and medium-sized businesses in India and make them more productive. According to a McKinsey online survey, only about 2.9 million Indian SMEs (about 8 percent) use e-business services for applications such as customer-relationship and supply-chain management, compared with 45 to 55 percent of SMEs in Vietnam.[12] If all of India's SMEs were to match Vietnam's adoption rate, an estimated 20 million SMEs could be using cloud-based services by 2025. India's government also plans to make a major commitment to cloud computing: it launched the government cloud initiative Meghraj in 2014 to create national and state clouds to speed up the development of e-governance applications and optimise government IT infrastructure.

Automation of knowledge work

Advances in artificial intelligence, machine learning, and natural user interfaces (such as voice recognition) make it possible to automate many knowledge worker tasks. Globally, automation of knowledge work is expected to have wide-ranging impact, by taking on work that was previously thought to be beyond the capability of computers, including answering customer service queries. Potential benefits in places such as India would include speech-recognition-based search that brings digital information to the illiterate, and adaptive learning systems that observe student performance and customise online teaching material, based on mastery of knowledge and skills demonstrated in online assessments. SMEs could use applications enabled by automation of knowledge work technologies to improve efficiency, too. The owner of a shoe factory, for example, might be able to optimise production planning by using an intelligent application that schedules raw materials purchases by combining data analytics and human-like judgment about seasonal variations in demand, patterns in consumer preference, orders on hand, and stocks available.

12 *Online and upcoming: The Internet's impact on India*, McKinsey Technology, Media, and Telecom Practice, December 2012.

By 2025, India is likely to have 700 million to 900 million smartphone users connected to the mobile Internet. Via the cloud, these users will have access to a variety of applications that use automation of knowledge work technologies.[13]

Digital payments

India has a huge number of people who cannot receive or make payments other than with cash. Lack of access to bank accounts; personal credit; health, crop, or business insurance; and low-cost payment channels limits productivity for small business owners and farmers and makes many Indians economically vulnerable. Technologies that enable basic financial services for individuals in a secure and verifiable way could bring disruptive change to India by enabling millions of citizens to move into the modern economy and safely pay for a wide range of services from their mobile phones. A committee commissioned by the Reserve Bank of India in 2013 to assess the potential impact of electronic payments recommended that by 2016 every Indian resident above the age of 18 should have an individual, full-service, safe, and secure electronic bank account and be within a 15-minute walk of an electronic payment access point.[14]

Mobile money can play a central role in achieving these goals of universal financial inclusion. The volume of mobile payments through the Immediate Payment Service is already taking off in India. For millions of rural Indians, ownership of a mobile phone will precede ownership of a bank account, paving the way for rapid adoption of m-payments. According to the Reserve Bank of India, India had 1.5 billion retail electronic and card payments in 2013; the number could reach 12 billion in 2025 if the bank's target of universal financial inclusion is realised.[15]

Verifiable digital identity

A system of verifiable digital identity is critical for services such as e-commerce, digital payments, and other electronic transactions, for accessing online government services (to apply for benefits or licences, for example), and for establishing workers' identities at hiring. Most Indians rely on paper-based records (such as ration cards, voter cards, or passports) as proof of identity to sign up for school or apply for benefits. Such documents cannot be used to verify identity digitally, a major obstacle in moving many services online and reducing leakage in aid programmes. Verifiable digital identity can make online processes accessible and convenient for consumers, reduce handling costs for service providers, and prevent fraud. Another important benefit is national portability; a digital identity is recognised wherever the citizen goes, reducing barriers to labour mobility.

The required strength of identity security varies by the type of transaction or service. In some cases a mobile phone number with a password will be sufficient. The growth of e-commerce and mobile banking has, for instance, led to wide use of two-part digital verification systems (mobile phone number and one-time password). In other cases, where government services or financial

13 A "smartphone" is defined as a data-centric, cellular handset or cellular PDA with a branded, high-level operating system that is open to third-party applications, encourages data-centric activities, and is typically capable of multitasking. The Strategy Analytics Wireless Smartphone Strategies service, a data provider, estimates that the number of smartphone users in India will grow from 60 million in 2013 to 225 million by 2017.

14 *Report of the Committee on Comprehensive Financial Services for Small Businesses and Low Income Households*, Reserve Bank of India, December 2013.

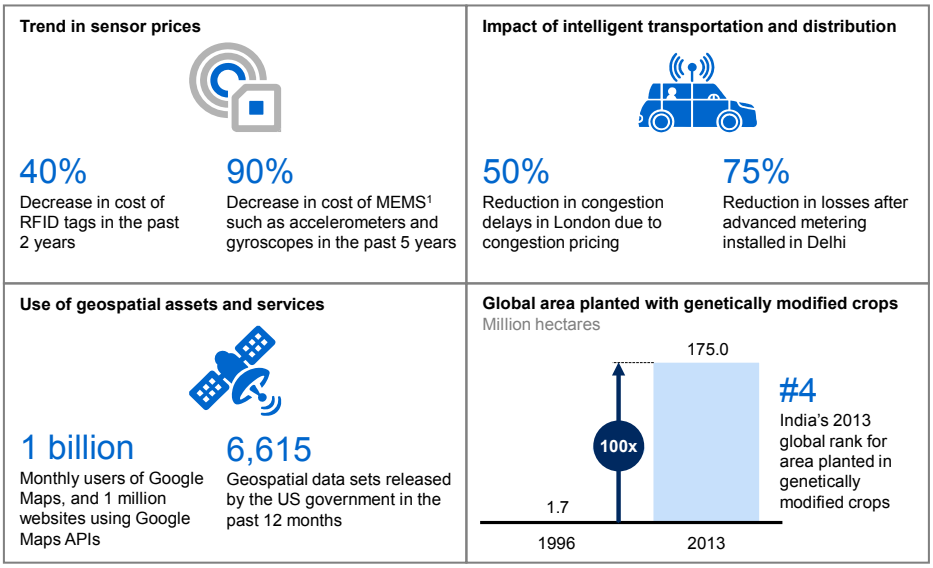
15 *Payments system in India: Vision 2012–15*, Reserve Bank of India, October 2012.

transactions are involved, highly secure biometric-based identity verification (retina or fingerprint scanning, for example) may be necessary. Now, under the Unique Identification Authority of India initiative, which administers the Aadhaar card programme, 24 million unique biometric citizen identities are being issued each month. By June 2014, about 580 million cards had been issued.[16] Verifiable digital identities are expected to be ubiquitous in India by 2025, potentially making possible many new kinds of services.

Smart physical systems

Smart physical systems embed computer intelligence into the physical world or apply advanced digital technologies to the development of things such as new materials and drugs. The empowering technologies for India that fall into this category are the Internet of Things, intelligent transportation and distribution systems, advanced GIS, and next-generation genomics. These technologies are at an earlier stage of adoption than purely digital technologies, but they show signs of rapid growth and could achieve significant levels of adoption by 2025 (Exhibit 6).

Exhibit 6
Adoption of technologies that embed intelligence in the physical world


Trend in sensor prices
40%
Decrease in cost of RFID tags in the past 2 years
90%
Decrease in cost of MEMS[1] such as accelerometers and gyroscopes in the past 5 years
Impact of intelligent transportation and distribution
50%
Reduction in congestion delays in London due to congestion pricing
75%
Reduction in losses after advanced metering installed in Delhi
Use of geospatial assets and services
1 billion
Monthly users of Google Maps, and 1 million websites using Google Maps APIs
6,615
Geospatial data sets released by the US government in the past 12 months
Global area planted with genetically modified crops
Million hectares
175.0
100x
1.7
1996
2013
#4
India's 2013 global rank for area planted in genetically modified crops

1 Micro-electromechanical systems.

SOURCE: *Smarter sensors: Making the Internet of Things soar*, Institute of Electrical and Electronics Engineers, March 2014; *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013; Tata Power NDPL Directors' report; Google; Geoplatform.gov; International Service for the Acquisition of Agri-Biotech Applications; McKinsey Global Institute analysis

The Internet of Things

The Internet of Things involves the use of sensors and actuators in machines and other physical objects so that they can be connected to digital networks and monitored and controlled remotely. Miniaturisation makes it possible to install sensors in even the smallest devices. Many smartphones, for example, have a single chip that includes a positioning sensor and a motion detector. Many of these smart devices, in conjunction with other technologies such as intelligent

16 Unique Identification Authority of India.

transportation systems and advanced GIS, have potential for huge impact in India by making its infrastructure, agriculture, and logistics systems more efficient.

Adoption of Internet of Things technology is accelerating globally as prices decline for RFID tags and sensors. Sales of sensors have grown by 70 percent annually since 2010. In the coming decade, sensors and actuators may be embedded in almost every type of machine and physical asset. In 2013, an estimated nine billion "things" were connected around the world. The estimates of what this number will be by 2025 vary from 50 billion to one trillion.[17] This will enable Internet of Things devices to monitor and control flows of people, goods, and services just about anywhere. India could expect to have anywhere from two billion to ten billion Internet of Things devices in operation by 2025.

Intelligent transportation and distribution

These technologies use computer intelligence and systems engineering—as well as Internet of Things technologies such as sensors—to understand and optimise the movement of people, goods, electricity, and water. They vary from simple applications such as traffic signal control and container management, to speed camera systems that automatically issue traffic violations, to real-time data systems that track weather changes and enable planning for floods and other weather emergencies. Intelligent transportation systems can facilitate trade by creating faster transportation. They can also help improve safety on trains and roads by using computers and remote sensors to monitor speeds and adjust schedules, an important application for India.

Intelligent monitoring systems along with Internet of Things tracking devices can be used to track food and drugs in transit to prevent tampering and can reduce pilferage of resources such as coal, grains, cement, and fertiliser. Intelligent distribution systems can manage the flow of water to reduce the proportion lost to leakage and theft, which is currently 46 percent in India. Smart grid technologies are a form of intelligent distribution and can reduce transmission and distribution losses, which are currently 24 percent in India. These applications will have even greater potential benefits as India's population grows, placing greater demands on electricity and water systems.

By 2025, intelligent transportation technology could optimise traffic flow on a substantial share of India's 115,000 kilometres of railway track, improve container and cargo handling at many of India's 200 ports, and improve commuting in at least 50 Tier 1 and Tier 2 cities. India can aspire to have smart electricity and water metering in 60 to 80 percent of Tier 1 and Tier 2 cities by 2020, a level similar to that of the European Union today.

Advanced GIS technologies

Advanced geographic information systems allow integration of multiple maps and images with geotagged data. They can be used to map spatial data (such as flooding patterns in a city) and identify relevant features and structures (emergency centres close to flood zones, for example). Based on such criteria, they can determine which emergency centres need additional support. Advanced GIS data are also important for precision farming—combining geographic information with data on soil conditions and other factors to show farmers exactly

17 Joseph Bradley, Joel Barbier, and Doug Handler, *Embracing the Internet of Everything to capture your share of $14.4 trillion*, Cisco, 2013.

when to plough, plant different crops, and water fields. Advanced GIS can also help in disease and epidemic control programmes, by enabling health officials to make quick and effective decisions. For example, in the case of outbreaks of infectious diseases, timely geospatial information about the spreading pattern of the disease could help in containing the infection to a specific region through effective quarantine techniques.

GIS growth has been explosive over the past decade; more than 54 percent of global smartphone owners used Google Maps at least once a month in 2013, for example. China, Brazil, and Indonesia plan to develop nationwide GIS data projects. In India, the Planning Commission has proposed the creation of a national GIS asset for use in public service delivery, health care, agriculture, water and natural resources, land records, and many other areas. This could help India integrate rich and multilayered GIS data into many consumer, government, and business applications.

Next-generation genomics

Next-generation genomics marries advances in the science of sequencing and modifying genetic material with the latest big data analytics techniques. The technology has been accelerating at an astonishing rate. When the first human genome was sequenced in 2003, it cost nearly $3 billion and took 13 years. Now a sequencing machine may soon be available for less than $1,000 that will be able to sequence a human genome in a few hours. Advanced genomics promise to play a critical role globally in addressing health-care needs through medicines that are tailored to particular patients, including cancer therapies based on the genetics of a particular tumour and advanced gene-based therapies for diabetes. These diseases account for about half of the ten million deaths in India each year, providing a large potential for impact.

Hybrid and genetically-modified (GM) crops have helped boost the output of non-food crops (such as jute) and food crops (such as corn and soybean), by making them more pest- or drought-resistant. The total area planted worldwide in GM crops rose from 1.7 million hectares globally in 1996 to more than 170 million hectares in 2012. So far, India has about 18 million hectares (9 percent of cropland) planted in hybrid and GM varieties. GM is subject to widespread environmental, societal, and consumer concerns, and this could limit its future adoption rate.

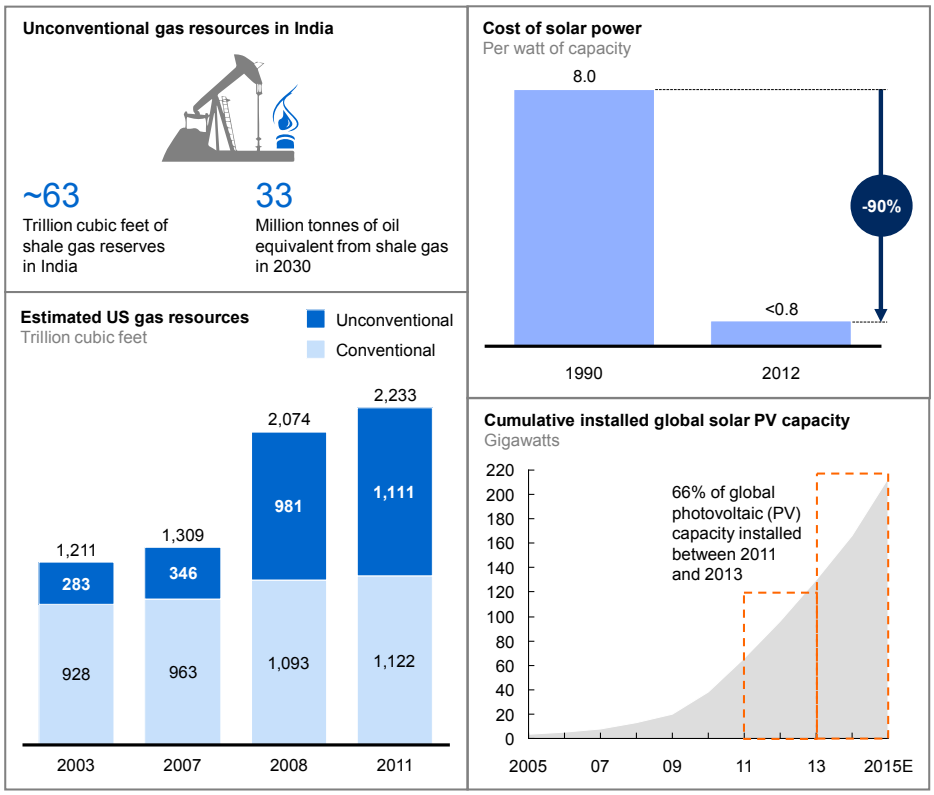
Rethinking energy

The global energy sector is experiencing its own technology revolution. The energy technologies that will matter to India are the same as those that are making disruptive change globally: unconventional oil and gas (horizontal drilling and hydraulic fracturing), renewable energy (wind and solar), and advanced energy storage. These technologies are essential for reducing India's dependence on energy imports and making electricity more reliable and available. Some 300 million people in rural India do not have an electricity connection, and where power supply is available, it is often erratic and poor in quality.[18] Energy technologies that give households and enterprises affordable, clean, and reliable power are critical for economic growth and social development. Reliable electricity is also essential for other technology-based services enabled by the

18 *World energy outlook 2013*, International Energy Agency, November 2013.

mobile Internet, cloud services, and the Internet of Things. Exhibit 7 shows the extent of unconventional and renewable energy resources in India.

Exhibit 7
Potential for rapid growth in energy from unconventional and renewable sources



SOURCE: US Energy Information Administration; Greentech Media; McKinsey Global Institute analysis

Advanced oil and gas exploration and recovery

The technology for extracting unconventional oil and gas deposits—such as those imbedded in shale formations—is advancing rapidly. For example, new modelling techniques could cut in half the time it takes to understand basin behaviour. Development of unconventional oil and gas fields is most advanced in the United States and Canada, but other nations are also beginning to develop their reserves. Globally, technically recoverable reserves (known reserves) of shale gas are estimated to be 7,299 trillion cubic feet. India's reserves of shale gas and coal-bed methane (which is recovered using methods similar to fracking) are estimated at 130 trillion cubic feet. Developing these reserves could help make India more energy independent and limit carbon emissions by using more gas for electricity generation. The Energy Information Administration estimates that India could produce 235 billion cubic feet of natural gas in 2025 by tapping unconventional reserves.

Renewable energy

Solar and wind energy have not matched fossil fuels on a pure cost basis everywhere, but costs are falling and significant additional adoption is widely expected by 2025. Renewable sources are expected to account for 18 percent of global primary energy use in 2035, up from 13 percent in 2011.[19] With falling costs and higher government subsidies (in some markets), solar adoption is accelerating; some two-thirds of global photovoltaic solar capacity was installed between 2011 and 2013. India's Planning Commission forecasts that solar and other renewables could account for some 9 to 10 percent of India's energy consumption, or about 43 gigawatts per year, in 2025.

Advanced energy storage

Globally, advanced energy storage technology plays a critical role in transportation (through hybrid and all-electric vehicles) as well as in electricity supply. The price of lithium-ion battery packs for electric vehicles has fallen 40 percent since 2009, and MGI estimates that at least 40 percent of vehicles sold globally in 2025 could be electric or hybrid.[20] In addition, battery storage is helping bring reliable electric supply to underserved places, improve the reliability of the electric grid, and enable the integration of renewable energy sources such as wind and solar. To bring electricity to remote areas, a South African company has come up with a combination solar charger and battery storage unit that lets consumers in remote areas generate enough electricity to power a cellphone, a computer, a radio, and lighting. The system is being made available on a pay-as-you-go basis, with customers making mobile payments based on usage.[21] On-grid storage can be used by utilities to accommodate peak demand without adding new capacity and to integrate wind and solar, which are intermittent energy sources (batteries are used to store electricity generated by solar during the day or by wind turbines during windy times for use at other times).

HOW EMPOWERING TECHNOLOGIES CAN TRANSFORM ENTIRE SECTORS

The empowering technologies we identify can have massive economic and social impact by reducing costs, expanding access to services, delivering more consumer value, and reducing inefficiencies. The major technology-based services and innovations that can produce economic and social impact in India by 2025 are summarised in Exhibit 8. Each of these technologies and applications creates value on its own, but they are even more powerful when used in combination, potentially transforming entire value chains (see Box 3, "Reimagining whole delivery systems").

19 *World energy outlook 2013*, International Energy Agency, November 2013.

20 *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

21 "MTN Uganda launches pay-as-you-go solar power system", HumanIPO.com, December 18, 2013.

Exhibit 8

Multiple technology applications can be combined to create large economic and societal impact

Technologies	Sectors						
	Financial services	Education and skills	Health care	Agriculture and food	Energy	Infrastructure	Government
Mobile internet	▪ Universal electronic bank accounts ▪ Technology-enabled banking correspondents ▪ Mobile money ▪ Advanced credit underwriting ▪ Enhanced customer experience ▪ Digitisation of sales and fulfilment	▪ Hybrid learning with MOOCs ▪ Low-cost instructional devices ▪ E-administration of educational institutions ▪ Online teacher training and certification ▪ Adaptive learning ▪ Learning simulations for skills ▪ Labour portals	▪ Remote health care ▪ Technology-enabled community health-care workers ▪ Electronic medical records ▪ Automated inpatient care ▪ Low-cost diagnostic devices ▪ Remote monitoring devices and apps	▪ Real-time market information ▪ Remote and e-enabled agricultural extension and advisory services ▪ Technology-enabled crop insurance			▪ E-government services for citizens and businesses ▪ Automated core government processes ▪ Big data analytics-based decision support systems
Cloud technology						▪ E-enabled project management systems ▪ Smart cities	
Automation of knowledge work							
Digital payments	▪ Digital government payments ▪ Direct transfers of benefits	▪ Digital consumer and SME payments					▪ Direct transfers of government benefits
Verifiable digital identity		▪ Verifiable identity-based attendance monitoring					▪ Technology-enabled public safety and surveillance systems
Internet of Things			▪ Detection of counterfeit drugs	▪ Precision farming using sensors ▪ Technology-enabled agricultural supply chains ▪ Leakage-free public distribution system for food ▪ Precision farming using hydrology and soil mapping ▪ Hybrid and/or genetically modified crops	▪ Advanced metering systems for power and water		
Intelligent transportation and distribution						▪ Integrated freight logistics ▪ Highway management	▪ Real-time disaster management ▪ Dynamic, integrated resource planning systems ▪ Digitised land records
Advanced GIS			▪ Big Data–based disease tracking and management			▪ Water treatment and waste management systems	
Next-generation genomics			▪ Genomics-based personalised medicine				
Advanced oil and gas exploration and recovery					▪ Fuel supply from shale oil and gas, coal-bed methane		
Renewable energy	▪ Rural electrification				▪ Electricity from PV solar ▪ Offshore wind and seaweed		
Advanced energy storage	▪ Stable power systems						
				▪ Energy-efficiency improvement technologies			

Integrated impact of technology applications in each sector							
Economic impact in 2025	$30–140 billion	$60–90 billion	$25–65 billion	$45–80 billion	$50–95 billion	$30–45 billion	Not separately sized
People reached	320 million with financial service access	100 million students with better learning outcomes; 100 million workers trained with skills	400 million rural residents with affordable health-care services	90–100 million farmers; 300–400 million food subsidy recipients	80–100 million people with electricity supply	10 million affordable homes	Not separately sized

SOURCE: McKinsey Global Institute analysis

Box 3. Reimagining whole delivery systems

When technologies and applications work together, they reinforce each other and have the power to challenge traditional constraints and create substantial economic and social value. In India, combinations of technologies could be used to reimagine the systems for delivering education and health-care services, subject to the right policies and regulation, and efforts to reduce barriers to adoption.

Reimagining education and learning. The fundamental constraint India's education sector faces is the variability in learning in schools and colleges. This is due to many factors, including poor attendance (by students and teachers), poorly trained teachers, and a lack of systems to track and manage performance.

In the future, Indian students may attend schools where both student and teacher attendance is tracked through systems that check verifiable digital identities or with mobile Internet devices. The teacher might use a tablet to teach scripted lessons to the class that come across the mobile Internet from the cloud; individual students could receive customised lessons on a computer or tablet based on their progress on frequent assessments—also with the help of cloud-based applications. The teacher could take online courses to update content knowledge and build classroom skills. Frequent assessments would be administered electronically, and results would be collated, analysed, and reported to school administrators, teachers, parents, and students. The school would receive incentives based on performance. With electricity supplied by solar collectors and batteries, these teaching and education management methods could be used nearly anywhere. Millions of Indians, including adults in need of vocational training, could acquire skills relevant to the labour market.

Reimagining affordable health care. The fundamental constraints in India's health-care system are the limited number of trained doctors and nurses (particularly those who are willing to practise in poor, rural communities), the number of health-care facilities, and unhealthy conditions caused by poor access to clean water and sanitation. Today, a rural Indian might leave most ailments undiagnosed and untreated, or would suffer high cost and hardship in an attempt to reach a facility to be diagnosed and treated.

Working together, empowering technologies can transform health care in India. With the mobile Internet and knowledge systems in the cloud, for example, community health workers (including traditional healers) can bring preventive health measures and some basic primary care to Indians in remote areas. Intelligent tablet-based applications based on expert medical knowledge could assist the care workers in screening and monitoring. The mobile Internet would make the specialist knowledge of physicians in far-off cities available to workers in health centres and call centres. Low-cost medical diagnostic devices that attach to smartphones and are powered by efficient energy-storage cells would make many visits to clinics unnecessary (see Chapter 4 for more detail). Internet of Things sensors could ensure that genuine drugs, rather than counterfeits, are dispensed, and advanced GIS can vastly improve responses to disease outbreaks—combining map data and crowdsourced reports on new cases that can be analysed by intelligent systems to deploy resources most effectively. Diseases can be prevented by using Internet of Things sensors to monitor water quality. Together, these innovations could contribute to sustainable improvement in health outcomes for millions of Indians.

ECONOMIC IMPACT OF $550 BILLION TO $1 TRILLION A YEAR IS POSSIBLE IN 2025

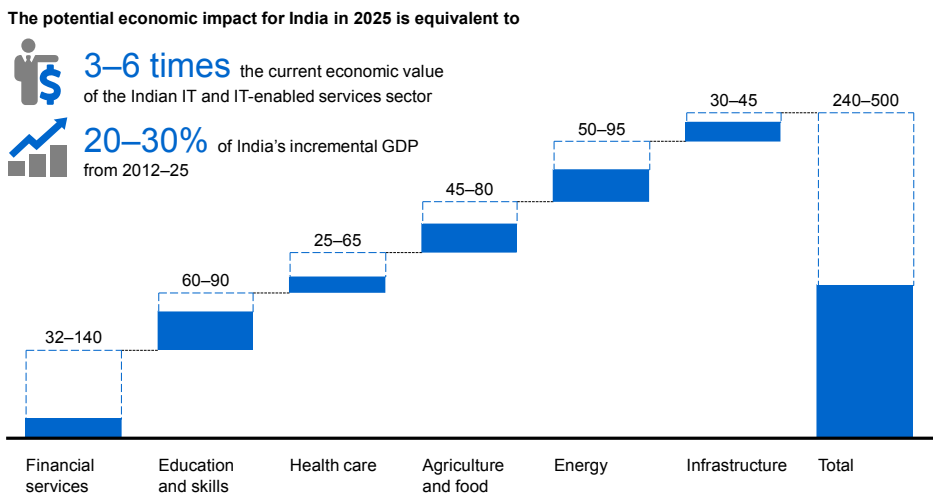
Assuming the 12 empowering technologies are adopted in line with the aspirations we set for India in 2025, we estimate that they can have a combined economic impact of $550 billion to $1 trillion per year in 2025 (Exhibit 9). These estimates do not represent GDP, market size, or revenue (see Box 4, "Approach to estimation of potential economic impact in 2025"). Rather, they are an indication of cost savings, efficiencies, and increased consumer surplus, such as lower prices, and time and lives saved, as well as reduction of leakage and waste in government services.

Exhibit 9

Economic impact of empowering technologies could be $550 billion to $1 trillion in 2025, with $240 billion to $500 billion from sized applications

Potential economic impact in 2025

Sized applications in six sectors ($ billion)



Notes on sizing

- Estimates of economic impact are not comprehensive and include potential direct impact of sized applications only.
- These estimates do not represent GDP or market size (revenue), but rather economic potential, including consumer surplus. Comparisons with GDP are only illustrative of the potential scope of impact.
- These estimates are not achievable through technology alone. They assume that enablers, such as training, incentives, and infrastructure, are put in place to capture the full potential value.
- Relative sizes of impact shown here cannot be considered a "ranking" because sizing is not comprehensive.
- We do not quantify the split or transfer of surplus among or across companies or consumers. Such transfers would depend on future competitive dynamics and business models.
- Estimates are not directly additive due to partially overlapping applications and/or value drivers.
- The estimates are not fully risk- or probability-adjusted.

NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

We estimate this range of economic impact in 2025 based on both top-down and bottom-up approaches. From a top-down perspective, we start with MGI's global estimates of potential economic impact of $14 trillion to $33 trillion per year in 2025 from disruptive technologies. Based on India's share of global GDP, its expected growth, and the potential scope of the technologies we consider, we estimate it could realise 7 to 8 percent of the total impact among developing economies. This brings us to the $550 billion to $1 trillion range.

Globally, MGI estimates that disruptive technologies could account for 25 to 30 percent of world GDP growth from 2014 to 2025. More than one-third of this impact would come from the mobile Internet and the automation of knowledge work. We estimate that India's empowering dozen can drive 20 to 30 percent of incremental GDP growth in the coming decade, largely through productivity gains

Box 4. Approach to estimation of potential economic impact in 2025

We estimate the potential economic impact of 12 technologies across a set of applications, based on feasible scenarios for technology advancement, reach, and resulting productivity or value gains that could be achieved by 2025. We focus on estimating the potential (rather than realised) value in 2025 by assuming that addressable barriers to technology adoption and value creation (such as the need for supporting regulations) can be overcome and that reasonable, necessary investments can be made.

We first identify applications and drivers of value for each technology. We then define a scope of potential impact for each application (for example, the number of individuals who do not have banking services), which we project to 2025 to create a hypothetical base case for each technology. Potential rates of adoption are estimated (for example, the share of electricity production from renewable sources, or the share of financially excluded consumers who open bank accounts using technology-enabled services), taking into account price and performance improvement globally as well as expectations for India based on local barriers and the absence or presence of enablers, such as government support for broadband access. Finally, we estimate potential productivity or value gains from each application that could be achieved across our defined scope of impact by 2025 (for example, the difference between the cost of conventional and unconventional sources of energy, or the additional productivity that small businesses could derive from access to financial services) to determine the potential direct economic impact of the use of the technology for this application.

from digital technologies. However, realising such gains in India is complicated by its low starting point: the Internet economy in India was just 1.6 percent of GDP in 2011, compared with 3.4 percent in developed countries and 2.0 percent in a set of aspiring countries such as Brazil, China, and Malaysia.

To validate the top-down estimate and gain a more detailed understanding of the drivers of value, we sized the potential economic impact in 2025 in seven select sectors. Across these, we estimate the potential economic impact of a set of technology-enabled applications at $250 billion to $500 billion per year in 2025.[22] Scaling these estimates up based on the GDP of these sectors would lead us to a similar figure for total economic impact of $550 billion to $1.1 trillion in 2025.

The potential economic impact of $550 billion to $1 trillion per year in 2025 is equivalent to 20 to 35 percent of India's incremental GDP between 2012 and 2025, or 16 percent of India's potential GDP in 2025 (about the same share as the manufacturing sector has in India's economy today). This figure represents three to six times the value added today from India's IT and IT-enabled services industries (business process outsourcing, for example).

The potential economic benefit we estimate comes with potential risks and costs (that we do not quantify). The mobile Internet raises issues involving privacy and intellectual property protection that need to be addressed. Consumers, businesses, and trading partners will want to know what protections exist for them as they conduct business on the Internet in India. The Internet of Things offers unprecedented potential for hackers and cyberterrorists to cause havoc by interfering with physical systems; defences and safeguards will need to be built

22 We do not size the economic value of technology interventions for government services separately; many of the applications in government services are sized within the sectors they impact, such as health or education. The total impact size represents only the potential economic impact of a specific set of technology-based services that we could size; it is not a comprehensive sizing of all possible impacts, nor does it take into account the effects of interactions among multiple applications.

and continuously refined. As the Internet (mobile and wired) becomes an essential service for the Indian people and economy, data security and network reliability will become of utmost importance. Spending on communication infrastructure will need to grow, and radio spectrum will need to be managed better.

There are also significant implications for sustainability and natural resources that need to be assessed and managed. Oil and gas technologies carry the risk of environmental damage, and genetic seeds and gene-based treatments raise questions about biodiversity and medical ethics. The proliferation of technology-based applications and services implies that demand for energy will accelerate, and innovation in energy-efficiency technologies, renewables, and energy storage must keep up. Regulators and policy makers will need to inform themselves about these issues, weigh the risks, and, in concert with the public, make judgments about the safeguards necessary.

POTENTIAL IMPACT ON VARIOUS SEGMENTS OF SOCIETY

Beyond their economic impact, these technologies will change how India lives and works. Impact will be felt by consumers, workers, small businesses, entrepreneurs, and large businesses.

Consumers: Access to the basics and better quality of life

If India follows the pattern of other nations, consumers are likely to capture the largest share of value from disruptive technologies. Around the world, access to the Internet and digital services has created consumer surplus and improved the quality of life for ordinary citizens. Many technology-enabled services that we highlight in this report—such as remote health care, computer-based instruction, technology-enabled food distribution, mobile money, and solar energy—can offer significant improvements in the lives of poor Indians. By 2025, we estimate that:

- Technology-enabled primary health-care centres and community health-care workers could reach 400 million people who otherwise would have access to no care or only poor quality treatment.
- Mobile technology (assuming that required regulatory changes are made) could nearly double the rate of financial inclusion and bring more than 300 million people into the formal financial system, giving them access to remittances, credit, and life and health insurance.
- New energy technologies, including advances in storage, could increase output of reliable power and expand access to electricity to 80 million to 110 million people.
- The nutrition of 200 million to 250 million Indians could be improved if they receive their full entitlements of subsidised food through a secure online benefits system; they could also benefit from lower food prices from better distribution and greater food diversity through precision farming and technology-enabled farm extension services.

Middle-class consumers also would benefit. We do not quantify the economic value of the consumer surplus generated by greater choice, convenience, and market transparency. However, the quality of life of India's consumers could be affected in multiple ways (see sidebar, "How life and work can be transformed by technology: Two vignettes from the future").

How life and work can be transformed by technology: Two vignettes from the future

A wide range of technology-based innovations will create value for Indians—as consumers, workers, and business owners. Some of these benefits can be anticipated and quantified; some are intangible. Here we present two vignettes to illustrate how life and work could change for individuals and small businesses in urban and rural India as empowering technologies take hold.

Reducing the friction of daily life

Neha is a young urban professional. She commutes to work on an efficient, high-speed transit system, using the time to order groceries and organise household services via apps on her mobile phone. At work, she completes design projects for overseas clients and spends an hour taking a MOOC class from a global university for her management degree. On the way home, she reviews her utility bills and pays them online. Last thing at night, she checks how her ailing parents are, using remote diagnostic devices, a cloud-based health monitoring service, and high-fidelity videoconferencing from her tablet.

Expanding small business horizons

Suraj owns a sari shop in a semi-urban part of India. He subscribes to a service that alerts him when nearby customers are shopping for saris, allowing him to respond instantly with photos and messages to promote a sale in his shop. He also sells his saris across the country on an e-commerce site and supplements his income by using his van to make local deliveries for an e-commerce footwear firm.

His son Raj, a driver for a car service in a faraway city, gets his work via an on-demand, online marketplace where customers post requests. He can charge more than other drivers because his customer ratings are among the highest. He remits money home instantly using his mobile phone.

Workers: Both risks and opportunities

Technology has been reshaping the labour force since the Industrial Revolution and continues to do so at an accelerated rate. Disruptive technologies, especially the automation of knowledge work, have sobering implications for many of the world's workers, since an increasing array of tasks involving human-like judgment can be automated. Workers in clerical functions and routine customer service will need to adapt and learn the skills to carry out higher-value tasks. Experts now believe that even work that requires specialised knowledge, such as legal and professional services (accounting, for example), could be automated as the intelligence of computing machines advances.[23] Workers who are displaced can find other types of work; in the past, technology advances have created new types of jobs as others were made obsolete. However, if workers do not attain new skills, the benefits of higher productivity could be concentrated among the most educated members of the labour force, leaving behind the less skilled.

Our global research suggests that applications such as automatic language translation and intelligent customer-service applications that can parse and answer customer questions could generate a 40 to 50 percent productivity gain in knowledge work. That would be equivalent to the output of 110 million to 140 million full-time workers around the world in 2025. However, recent MGI research in China indicates that despite the changes that will occur due to rapidly proliferating Internet technologies, the net impact from Internet applications on the total number of jobs could be neutral to slightly positive.[24] The research estimates that ten million to 31 million jobs (or about 1 to 4 percent of China's total labour force) could be eliminated between 2013 and 2025, while up to 46 million jobs could be created because of new market opportunities and expanded services enabled by Internet technologies (assuming workers have the skills to do the more value-added work).

Applying estimates from our global research suggests that the proliferation of systems using automation of knowledge work technologies could drive productivity equivalent to the output of some six million to eight million knowledge workers in 2025, ranging from clerical and customer service staff to business process outsourcing and IT workers.[25] Efficiency improvements will affect jobs in manufacturing, construction, trade, and transport sectors, too. Implementing digital applications, such as e-commerce, and automated supply chains, retail, and assembly lines, could yield potential savings equivalent to the output of an additional nine million to 17 million jobs in these sectors by 2025. In all, 5 to 8 percent of India's total labour force in 2025, or 19 million to 29 million workers in non-farm jobs, could be negatively affected by technology and may need to redefine their work (Exhibit 10).[26]

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23 Erik Brynjolfsson and Andrew McAfee, *Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy*, Digital Frontier Press, 2011.

24 *China's digital transformation: The Internet's impact on productivity and growth*, McKinsey Global Institute, July 2014.

25 These are broad estimates for India, assuming a 35 to 45 percent increase in productivity for a select set of knowledge worker occupations.

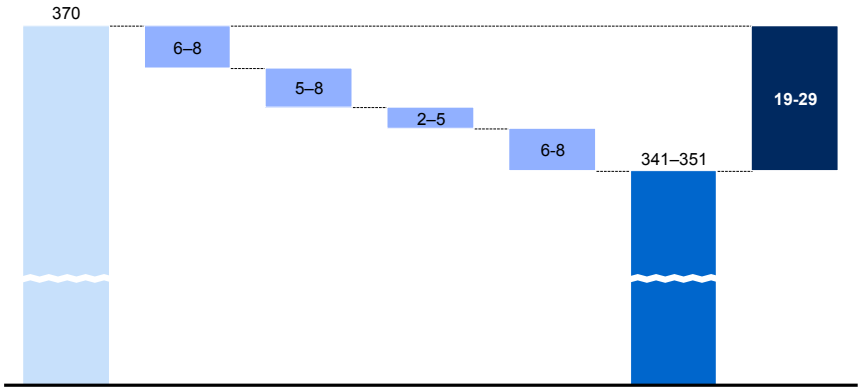
26 These are broad estimates, assuming impact levels similar to those estimated for the global labour pool and China's labour pools in MGI's research.

Exhibit 10

19 million–29 million non-farm jobs could be affected, implying a need for new employment opportunities and skills training

Non-farm jobs potentially impacted by the 12 technologies, 2025

Million



	Baseline non-farm labour force, 2025	Knowledge-based jobs[1]	Manufacturing jobs	Construction jobs	Trade, hospitality, transport, and other	Non-farm labour force with 12 technologies	**Workers needing new skills to maintain baseline**
Efficiency improvement rate[2] %		40–50	10–15	10–25	10–15		
Million addressable jobs in 2025[3]		17	78	95	180		
Adoption rate of technology applications[4] %		100	70	20	30		

1 Knowledge-based jobs in functions such as clerical and administration, legal, finance, engineering, teaching, and general management.
2 Broad estimates of efficiency improvement rates and adoption rates, based on MGI's global research on disruptive technologies, expert interviews on efficiency improvement potential from supply-chain automation and construction efficiency improvement in India, and the impact of e-commerce on jobs from MGI's China research.
3 Based on for the year 2022 from MGI's labour demand and supply model for India.
NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

New skills will be in demand and new markets for goods and services will be created, but we do not project the net impact of these forces against the rate at which jobs may become unnecessary or uncompetitive. In reality, the labour market will adjust more smoothly if workers are equipped to shift to more value-added work. However, the typical worker in India has many fewer years of schooling than a worker in many Asian countries. While India rivals China in university graduation rates, the share of people with secondary-school education in India is only about one-third that of China.[27] Issues with teaching quality and student achievement in India are also well recognised.[28] This problem needs to be addressed with utmost urgency. An estimated 100 million students will go through schools and enter the labour force between 2012 and 2025, and these young people present an opportunity to create a more adaptable workforce that is equipped for higher tasks. This can only happen if the education system can be drastically and rapidly improved. Employers, too, will need to do their part—redefining jobs to remain competitive and retraining workers to fill them.

27 See *The world at work: Jobs, pay, and skills for 3.5 billion people*, McKinsey Global Institute, June 2012, for a fuller discussion.

28 Abhijit V. Banerjee and Esther Duflo, *Poor economics: A radical rethinking of the way to fight global poverty*, Public Affairs, 2011.

On the positive side, the empowering technologies can give workers access to skills they previously lacked, open up avenues for productive work even for less-skilled workers who can be enabled by computerised know-how, and enable efficient labour marketplaces through which to find decent paying work. Technologies such as adaptive learning (expert systems that customise lessons according to interactions with each student) and simulated learning (to impart vocational skills) can prepare Indians better for the workplace. We estimate that using new teaching technologies and delivery models could help bring vocational training to 18 million to 33 million more Indians by 2025.

Knowledge-enabled jobs could become possible for workers with modest levels of formal education as technology allows expertise to be transmitted via handheld devices and as advancements in voice, language, and graphic interfaces make expert systems easier to navigate. Just a few months of basic training can prepare even a semi-skilled person to become a productive knowledge-enabled worker. Examples of these types of jobs, which are being developed in India and around the world, include the following:

- **Community health workers.** In India, three million to four million health-care workers could be trained and equipped to deliver primary health care to rural and urban communities, and to connect via the mobile Internet with expert physicians through video, voice, or chat. In India's Tamil Nadu state, more than 100,000 rural primary health-care providers are being trained to use tablet-based systems for screening and diagnosis (for more detail, see Chapter 4).

- **Community teachers and trainers.** Some four million to six million teachers could be trained to become more effective learning facilitators in schools for children and for adults seeking vocational training. The Bridge International Academies network of more than 300 schools in Kenya, described in Chapter 3, is one example of how this model could work.

- **Financial agents or business correspondents.** From 500,000 to one million people with rudimentary literacy and numeracy could provide basic financial services such as account opening, cash and credit dispensing, and other banking services in rural communities using mobile phones and micro-ATMs (Chapter 2).

- **Community farm extension workers.** Between 500,000 and one million agricultural workers who have some familiarity with local farming practices and traditional methods could be trained to become farm extension workers, providing farmers with data on weather, soil, water, and market prices, as well as farming advice. The information would be accessed through handheld devices that use simple interfaces. As described in Chapter 5, this model is being piloted by the Grameen Foundation in Uganda.

- **Para-technicians for e-services.** An estimated one million to 1.5 million intermediaries could be trained to provide e-government services (such as registering to vote) and e-business services (such as tracking the delivery of ordered goods) to Indians with low digital literacy. These service providers could operate out of kiosks, *kirana* stores (small neighbourhood markets), their homes, or designated public spaces. As India's government rolls out e-government Common Service Centres in a public-private partnership model, many such job opportunities could be created.

Many pilots exist for such knowledge-enabled work, but deploying these services on a large scale will be challenging. The jobs need to pay well enough to attract workers. Consumers would need to pay a share of the cost rather than relying wholly on government subsidies. That would make this work like a market-based service and keep service providers responsive to consumer needs, though the government could contribute part of its social spending budget to create these networks of service providers. Mechanisms to set standards and certify workers for quality will be essential. Partnerships with technical and domain experts (such as agricultural universities, colleges of alternative medicine, and industry associations in banking and health care), and non-governmental organisations (NGOs) with grassroots experience in community service delivery could help bring skills and technology to these new types of knowledge workers.

Empowering technologies may also create more opportunities for India's millions of micro-entrepreneurs. India is a nation of small-scale, independent service providers. Its formal manufacturing sector has not been as successful in creating stable wage-paying jobs as China's manufacturing sector, and sources of formal service employment, such as the government, the financial sector, and IT-enabled services, account for a relatively small share of total employment. So workers in urban India rely heavily on marginal jobs, self-employment, and daily wage work. Using the mobile Internet and online portals, India's micro-businesses can reach new customers, establish their reputations, collaborate with others, and get more work (see Box 5, "New marketplace models for India's 'micro-entrepreneurs'?").

Box 5. New marketplace models for India's "micro-entrepreneurs"?

Around the world, new online marketplaces are taking shape, where businesses compete for customers, companies solicit bids for work, and excess capacity—unused conference rooms, cars, or factory time—is traded. China's online B2B marketplaces are giving its small and medium-sized manufacturing enterprises access to global customers and the opportunity to scale up quickly. This kind of platform can be adapted for India's micro-entrepreneurs, providing a way for them to offer their skills. Some possibilities include:

- **Marketplaces for flexible work.** Project-based or piecemeal work assignments would be funnelled to aggregators representing professionals such as legal or tax specialists or financial planners who want part-time or temporary employment.
- **Marketplaces for "free agents".** Consumers post requests for a certain type of work (chauffeuring or home repairs, for example) on the portal, which acts as a clearinghouse, providing information about availability. Service providers would also use the portal to offer their time and accept assignments.
- **Marketplaces for certified and quality-assured service providers.** This would be a virtual place where certified service providers (licenced electricians and nurses, for example) could connect with potential employers.

SMEs: Improved competitiveness and market access

Small businesses are critical to the Indian economy and can make a larger contribution by taking advantage of the mobile Internet and cloud-based services to capture efficiencies and reach new markets. SMEs account for about 17 percent of GDP and 40 percent of exports, and they employ 75 percent of the labour force in India. In a McKinsey online survey of SMEs in the formal sector (27 million of 35 million operate in the informal sector), 81 percent said they use the Internet, not far below levels in Malaysia (86 percent) and Vietnam (84 percent). But only 43 percent of Indian SMEs that responded to the online survey said they sell online, and only 41 percent purchased supplies and inventory online.

With the mobile Internet and cloud-based services, it is far easier for companies to do business online and digitise operations than to do it themselves. These tools also make it possible for businesses to modernise and maintain an online presence from virtually anyplace that mobile service reaches. This is already happening: of the 4,306 locations where eBay buyers and sellers are present in India, 1,000 are in rural areas.[29] Moving businesses onto the Web can help SMEs tap new markets—both in distant parts of India and overseas. If 50 to 60 percent of India's SMEs (both formal and informal) make greater use of digital technologies by 2025, that would mean 20 million SMEs could reach new markets and consumers and reap the benefits of higher productivity.

Entrepreneurs: More opportunities for innovation

The rapid diffusion of some of the technologies described in this report is creating a more favourable environment for entrepreneurs in India. Access to disruptive technologies such as cloud services, combined with lowered barriers to entry to develop and distribute a product via digital channels to a growing market of connected consumers, will create opportunities to develop new products and business models. The cost of launching a business has fallen dramatically with the advent of cloud computing capacity and cloud-based applications for communication, payroll, accounting, and other functions. In addition, large numbers of freelance and virtual workers can be engaged via the Internet. At the same time, access to capital is improving due to the growing interest of venture capitalists and other private-equity investors.

India has already produced Web-based upstarts, such as Flipkart (e-commerce), InMobi (mobile advertising), MakeMyTrip.com (online travel), and Justdial (online search), that have taken on incumbents in their fields. These businesses are reaching scale at a rapid rate. Flipkart and InMobi, which launched in about 2007, took just four to five years to reach a valuation of $1 billion; Mu Sigma (a data analytics firm launched in 2004) took nine years to reach that valuation, and Micromax (a mobile handset supplier), which launched in 1999, took 12 years.

The first wave of Indian Internet startups was constrained by the reach of the wired Internet and mostly copied proven business models from the United States. The next wave of startups will have far larger markets to tap thanks to what could be the second-largest base of mobile Internet users in the world by 2016. As the market for technology-based services scales rapidly, India could see an explosion of innovative solutions to uniquely Indian problems such as lack of reliable transportation services, payments, education, health care, and technology-

29 *India under a lens*, eBay India Census 2012, 2012.

enabled SMEs (see Box 6, "India's rapidly growing e-commerce market"). For this to come to pass, however, the government will need to move swiftly to simplify regulatory processes for the creation and dissolution of businesses, simplify tax and financing codes, and reduce the burden of regulations of payments and other services. The 2014 government budget includes a Rs. 10,000 crore ($1.6 billion) startup fund intended to act as a catalyst to attract private capital for new companies.

Box 6. India's rapidly-evolving e-commerce market

The disruptive power of e-commerce has not been felt yet in India. Only 0.3 percent of Indian retail sales took place online in 2013, compared with an estimated 8 to 9 percent in China and 6 percent in the United States.[1] But the pieces are falling into place for Indian e-commerce to take off: online retail sales are growing by 140 percent a year and, more importantly, Indian companies such as FlipKart and global players such as Amazon are developing e-commerce business models that are adapted to the unique challenges of the Indian economy.[2]

Pioneers learned that standard e-commerce models may not work well in the Indian context. For example, electronic payment systems are not well developed; Indians who have Internet access may not have bank accounts or credit cards. To get around this obstacle, some e-commerce companies engaged courier services to deliver orders and collect payments; 50 to 60 percent of online sales are completed with cash-on-delivery transactions.[3]

But the cash-on-delivery system is expensive and subject to fraud. So, e-commerce companies are adapting their models again by offering incentives such as discounts, free delivery, and chances to win prizes for customers making online payments. Also, courier services do not serve Tier 2 and Tier 3 cities where demand for online shopping is very strong because modern retail chains have not penetrated those markets. So companies have invested in their own distribution networks. Flipkart started an in-house logistics operation in 2010, then spun it off into a B2B logistics company, eKart, which reaches about 200 Indian cities.

Another factor that is shaping the industry is government regulation, which limits foreign direct investment in retailers but not in wholesalers. Both FlipKart and US-based Amazon now are experimenting with a marketplace model, similar to China's Alibaba, in which the companies operate online trading platforms for independent vendors. Amazon offers an end-to-end service for sellers, Fulfilled by Amazon, promising one-day delivery. It stores, packs, and delivers merchandise, handles returns, and is experimenting with using *kirana* stores as pick-up points for consumers.

Indian e-commerce should gather additional momentum as more Indians gain access to smartphones and electronic payment systems, and companies continue to invest in refining their business models. FlipKart says 20 percent of purchases are now made with mobile apps. Flipkart raised $1 billion from investors in 2014, and Amazon has announced plans to invest $2 billion in an Indian e-commerce business.[4] Customers, meanwhile, have begun to expect continuing innovation in service quality and delivery for digital services, even beyond e-commerce.

1 *China's digital transformation: the Internet's impact on productivity and growth*, McKinsey Global Institute, 2014; Accel Partners India e-commerce report, 2014.

2 www.internetlivestats.com.

3 Ibid.

4 Jitender Miglani, "Amazon India and Flipkart are betting big on India e-commerce growth," Forbes.com, August 7, 2014.

Established businesses: threats from disruptive business models

Established businesses will face both threats to their traditional profit pools and fresh opportunities as a result of disruptive technologies. They may need to evolve disruptive business models of their own to respond to four key trends:

- **Traditional sources of competitive advantage may erode rapidly.** Many established businesses derive value from strategic assets such as well-located branch networks, widely recognised brand names, and low-cost manufacturing facilities. Disruptive technologies may render many of these assets less valuable. For instance, the ability to target and serve customers anywhere and anytime in a personalised and intimate way through digital channels makes a convenient branch less relevant. Industries such as travel agencies, retail, hospitality, education, and restaurants, have found that their brick-and-mortar assets can turn into liabilities in the face of online competition, such as Web-based grocery and restaurant-delivery services. As digital platforms proliferate, all sorts of business models seem vulnerable. For example, with online car services such as Uber and Olacabs, which deploy independent owners, there may be little advantage to owning a fleet of taxis. While India is at the beginning of this shift, consumer expectations and willingness to pay for convenience and choice will only increase, creating opportunity for disruption across most industries. Today, for example, BigBasket is testing whether Indians are ready for online grocery shopping.

- **The new source of competitive advantage will likely be the ability to generate greater consumer surplus.** Businesses that exceed customer expectations on transparency and engagement will have more potential to create sustainable value. Customers likely will demand visibility into every element of their interactions with vendors and service providers. A retailer operating in an advanced economy today is expected to provide real-time tracking of online orders. Companies of all kinds are using social media to track customer sentiment and feedback, and many are crowdsourcing ideas for designs and new products. Customers are coming to expect to control and shape their relationships with vendors; shoppers want to specify not only the colour, style, and size of the garments they buy, but also the time and place of delivery.

- **Data and analytics capabilities could be key sources of advantage for large companies.** Organisations will be able to make important business decisions using multiple, diverse sources of data along with real-time analytics. The frequency of data-based decision making would increase, enabling continuous optimisation of processes to enhance customer lifetime value. The traditional sequence of consumer product development (strategy, prototype, market trials, launch) could collapse into a continuous cycle of market experimentation, data gathering, product optimisation, and re-introduction. Smart organisations will want to gather data from every customer interaction to make refinements and deliver more and more value to consumers.

- **Large organisations may also have to rethink talent strategies to compete in the digital business environment.** Specialists in data analytics may become the most strategically important resources, while other business functions may be outsourced. Leaders will likely have digital marketing backgrounds, appreciation for analytics, and mastery of data-driven processes; they will not be afraid to continuously reinvent business models to pre-empt would-be disruptors. The premium will rise for talent that is extremely comfortable working in a data-rich, highly automated, and fast-moving environment. Companies that can identify, source, attract, and retain such talent will have an edge.

□ □ □

Empowering technologies can have massive impact in India, perhaps creating value equivalent to 20 to 35 percent of India's incremental GDP. For this impact to materialise, access to empowering technologies needs to be broad-based. In the following chapters, we outline how each sector can be transformed to achieve broad-based impact, and the interventions that could enable faster harnessing of this potential.

2. Financial services

Over the past decade, India's banks have adopted technology-based business models, put in place an infrastructure for online payments and transactions, and created an array of online customer offerings. In short, the banking sector is ready to move ahead with seven technology applications that can bring banking services to more than 300 million "unbanked" Indians, make the transfer of $100 billion a year in government payments more secure and efficient, and create one million to 1.5 million jobs. We estimate the potential economic impact of these applications at $32 billion to $140 billion per year in 2025. In addition, we believe that the empowering technologies have the potential to disrupt Indian banking and financial services, forcing players to reinvent themselves and their core business models.

CHALLENGES TO INDIA'S BANKING SECTOR

India's private-sector banks have been pioneers in using technology to create hybrid "clicks and bricks" models that combine online and branch-based services, such as stock trading, mobile banking, and insurance sales. Public-sector banks have followed by digitising banking operations. By now, virtually all players have digitised core banking systems and offer online banking and cash management. The industry has an advanced payment infrastructure for secure settlement of both large and small transactions: the Immediate Payment Service and the Real Time Gross Settlement system. Now the industry is ready to take advantage of the opportunities afforded by the mobile Internet, cloud storage, automation of knowledge work, and other emerging technologies and applications. These can help Indian banks address three challenges:

Financial inclusion

An estimated 300 million Indians have no access to banking, which prevents them from accumulating savings or participating fully in the formal economy. Only 36 percent of rural Indians have bank accounts, and even those with bank accounts often do not have access to any other financial services, such as credit to buy farm equipment or fund a small business. Of some 170 million rural households in India, just 45 million to 50 million have access to formal credit, and one-third of them also borrow from non-formal sources, at punishingly high rates of interest.[30] In an effort to promote financial inclusion, in August 2014, the government announced a major initiative, the *Pradhan Mantri Jan Dhan Yojana*, to provide basic bank accounts, overdraft protection, electronic and mobile payments, micro-insurance, and other financial services for the poor. A key barrier to providing banking services to the rural poor has been the high cost of serving such customers through traditional channels, even though 100,000 commercial bank branches and more than 150,000 post offices offer savings services. Point-of-sale terminals (with limited facilities to withdraw cash) are plentiful in cities but

30 *Report of the Committee on Comprehensive Financial Services for Small Businesses and Low Income Households*, Reserve Bank of India, December 2013.

not in rural areas, where just 3 percent of the population is within easy reach of a payment point.[31]

Payment system inefficiencies

Payments of financial benefits (scholarships, pensions, and wages paid by government job-guarantee programmes, for example) have been moving from cash-based channels that are prone to leakage to direct deposits in recipient bank accounts. But the high number of unbanked recipients constrains this process. Based on published government data, we estimate that only about half of the wages under employment guarantee programmes reached intended beneficiaries in 2010, mostly due to diversion of cash payments.[32] Apart from leakage, a great deal of time and effort is spent making or accepting paper-based payments in government offices. This leads to delayed payments, large transaction loads, and unnecessary administrative and overhead costs, such as auditing and reconciling paper ledgers and payment records. One study indicated that these paper processes added 25 percent to the cost of the government payments system.[33]

Banking sector efficiency

The technologies in our list also open up opportunities for financial sector players to improve their own efficiency. Indian banks are already relatively cost-efficient, with cost-to-income ratios of 49 percent, compared with 75 and 77 percent for banks in the United Kingdom and the United States, respectively. But that ratio has been static for the past decade, and we estimate that India's banking sector can aspire to improve its cost efficiency to about 35 percent through streamlined business models and investment in technology.

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

We highlight seven technology-based services that have the power to reshape India's financial services sector in the coming decade (Exhibit 11).

The first four applications—universal electronic bank accounts, technology-enabled business correspondents, mobile money, and digital government transfers and payments—have the potential to advance financial inclusion in India, using combinations of the mobile Internet, digital payments, verifiable digital identity, and automation of knowledge work technologies. The remaining applications—advanced credit underwriting, enhanced customer experience, and digitisation of sales and fulfilment—are aimed at improving the performance of the banking sector and transforming how customers are acquired, engaged, and served.

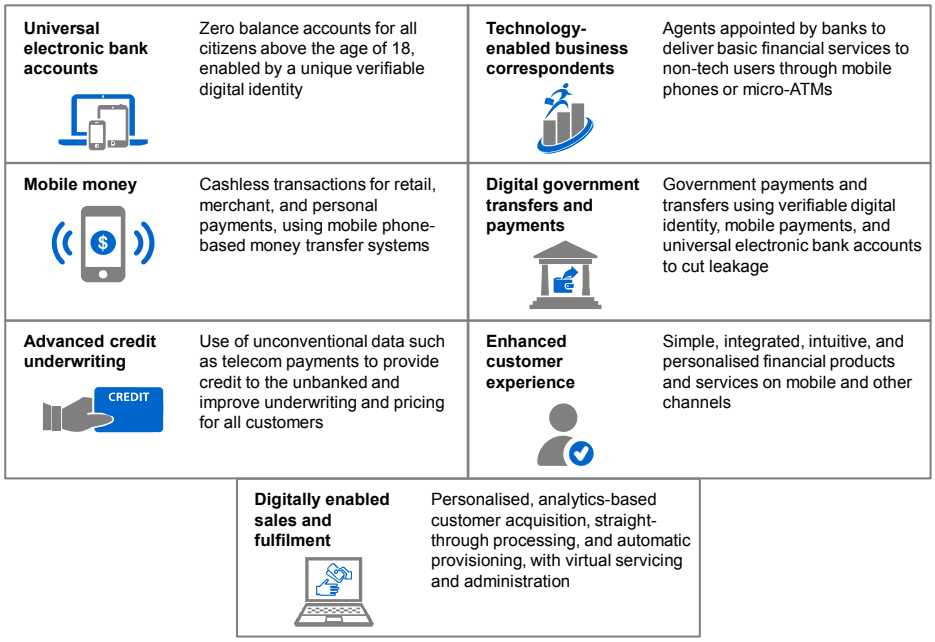
31 Ibid.

32 *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

33 *Inclusive growth and financial security: The benefits of e-payments to Indian society*, McKinsey & Company, November 2010.

Exhibit 11

Seven technology applications can transform India's financial services sector


Universal electronic bank accounts
Zero balance accounts for all citizens above the age of 18, enabled by a unique verifiable digital identity
Technology-enabled business correspondents
Agents appointed by banks to deliver basic financial services to non-tech users through mobile phones or micro-ATMs
Mobile money
Cashless transactions for retail, merchant, and personal payments, using mobile phone-based money transfer systems
Digital government transfers and payments
Government payments and transfers using verifiable digital identity, mobile payments, and universal electronic bank accounts to cut leakage
Advanced credit underwriting
CREDIT
Use of unconventional data such as telecom payments to provide credit to the unbanked and improve underwriting and pricing for all customers
Enhanced customer experience
Simple, integrated, intuitive, and personalised financial products and services on mobile and other channels
Digitally enabled sales and fulfilment
Personalised, analytics-based customer acquisition, straight-through processing, and automatic provisioning, with virtual servicing and administration

SOURCE: McKinsey Global Institute analysis

Universal electronic bank accounts

A committee appointed by the Reserve Bank of India recommended in January 2014 that each Indian resident above the age of 18 should have access to a universal electronic bank account and that no Indian be more than a 15-minute walk from an electronic payment access point. The recommendation also includes access to formal credit and investment products.

Universal electronic bank accounts would be the key vehicle for achieving financial inclusion. Electronic bank accounts are widely available in India, but easing the process for "know your customer" procedures will be critical to getting the estimated 300 million unbanked Indians into the system. To simplify the process of opening an account, the Reserve Bank of India in September 2013 said that banks can use digitally verifiable identity (such as an Aadhaar card) as a valid form of customer verification, making it possible for the account opening process to become paperless and nearly instantaneous when the Aadhaar card is issued (Exhibit 12). Separately, a Reserve Bank of India committee has proposed that a universal electronic bank account should be opened automatically whenever an Aadhaar card is issued. Another regulation that is under consideration would prevent banks from excluding low-value customers from opening a universal electronic bank account. In August 2014, the government announced the Pradhan Mantri Jan Dhan Yojana, in which 75 million unbanked families would be issued Aadhaar-linked bank accounts along with debit cards, accident insurance coverage, and a credit line within 6 months of opening the bank account. If the universal electronic bank account programme proceeds as planned, India will complete the largest financial inclusion programme in the world.

Exhibit 12

Enablers for a universal electronic bank account

Enablers

- **Universal proof of identity:** Digitally verifiable identity for all Indians approved by the Reserve Bank of India under "know your customer" rules
- **No entry barriers to account opening for identity holders:** Instructions to banks that they cannot refuse to open accounts for customers with valid proof of identity
- **Automatic account opening:** Account opening message sent to the bank automatically when digitally verifiable identity is issued

Features

- Lifelong validity
- Pay per transaction
- Zero balance account
- Mobile phone–registered

Simple account opening process

Register for digitally verifiable identity

Receive digitally verifiable identity card

Pick bank at which to open account

SOURCE: *Report of the Committee on Comprehensive Financial Services for Small Businesses and Low Income Households*, Reserve Bank of India, December 2013; McKinsey Global Institute analysis

Technology-enabled business correspondents

Setting up payment access points is another critical prerequisite to expanding financial inclusion. Using the mobile Internet and portable ATMs, the network of business correspondents who bring banking services to remote areas can be vastly expanded. Banking correspondents are licenced physical agents (businesses or individuals) that provide access to banking services to people who do not have access to bank branches. As of 2013, more than 220,000 correspondents had been deployed. A correspondent can open a no-frills savings account (with no minimum balance requirements), take deposits, dispense cash, send or receive money, and take payments for services. Correspondent networks, such as those operated by Eko and FINO, typically use inexpensive mobile phones that require two-step authentication to complete transactions; costs can be less than 1 percent of what a typical bank branch would charge.[34] Correspondents also use micro-ATMs, costing $250 to $500, to conduct transactions and dispense cash. Some of these devices can provide Aadhaar-based fingerprint identification and the interoperability of regular ATM networks.

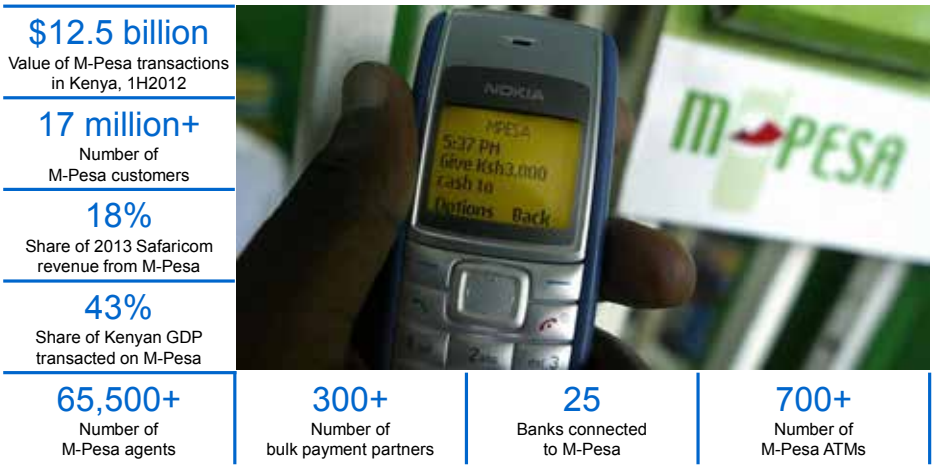
The correspondent banking channel has grown rapidly, with more than 300 million transactions routed through them in fiscal year 2013–14. Even so, small transaction sizes and low volumes have limited commissions for correspondents. Routing government payments and transfers through correspondents and expanding their service offerings to include credit products would help make them profitable and raise the motivation of banks to expand this channel. We estimate that more than $100 billion of government direct benefits can be routed through correspondents over the next two to four years, as well as domestic remittances of more than $3 billion. The upcoming introduction of licences for payment banks (non-bank institutions that take deposits) could enable national utilities and other institutions to create large-scale correspondent operations.

34 *Financial inclusion: From obligation to opportunity*, Confederation of Indian Industry and the Boston Consulting Group, March 5, 2011.

Mobile money

Mobile money is being adopted in many countries to promote financial inclusion. M-Pesa, a service of mobile phone carrier Safaricom, is the most celebrated and successful example, with 98 million of the 203 million registered mobile money accounts in the world (Exhibit 13).[35] What began as a basic payments platform in 2007 now serves as a foundation for multiple products, such as mobile insurance, mobile loans, and mobile savings. In Kenya, where M-Pesa started, an estimated 24 percent of GDP is transacted on the M-Pesa platform. The rapid spread of M-Pesa in sub-Saharan Africa is due in part to a favourable regulatory environment that permitted telecom players to lead the initiative. In addition to regulatory support, M-Pesa benefited from a powerful marketing campaign with the theme, "Send Money Home", and from Safaricom's dominant market position. More importantly, consumers found that sending and receiving remittances via M-Pesa was cheaper and safer than using cash.

Exhibit 13
Impact of M-Pesa mobile payments in Kenya



SOURCE: M-Pesa website and reports; Safaricom; McKinsey Global Institute analysis

The massive reach of mobile phones even in rural India (which already has an estimated 350 million subscribers) makes mobile money the most widespread and viable platform for financial inclusion in the country.[36] Several partnerships between telecom companies and banks have emerged to promote mobile money. Airtel Money has partnered with Axis Bank and Vodafone's M-Pesa with ICICI Bank. Still, adoption has been limited: in fiscal year 2012–13, just 23 million Indians of the 850 million mobile phone users had tried mobile banking.[37] Faster adoption would require better coordination between banks and telecom carriers and a focus on trimming costs. In addition, greater transaction flows and commission revenues are required for sales agents to become viable, and customer awareness could be increased in underserved segments and regions.

Another boost to adoption is the new regulatory framework that allows new kinds of payment banks. This would create an opportunity for non-bank players such as telecom companies to get banking licences, collect deposits, and provide

35 Claire Pénicaud and Arunjay Katakam, *State of the industry 2013: Mobile financial services for the unbanked*, GSM Association, February 2014.

36 Telecom Regulatory Authority of India.

37 *Report of the Technical Committee on Mobile Banking*, Reserve Bank of India, February 2014.

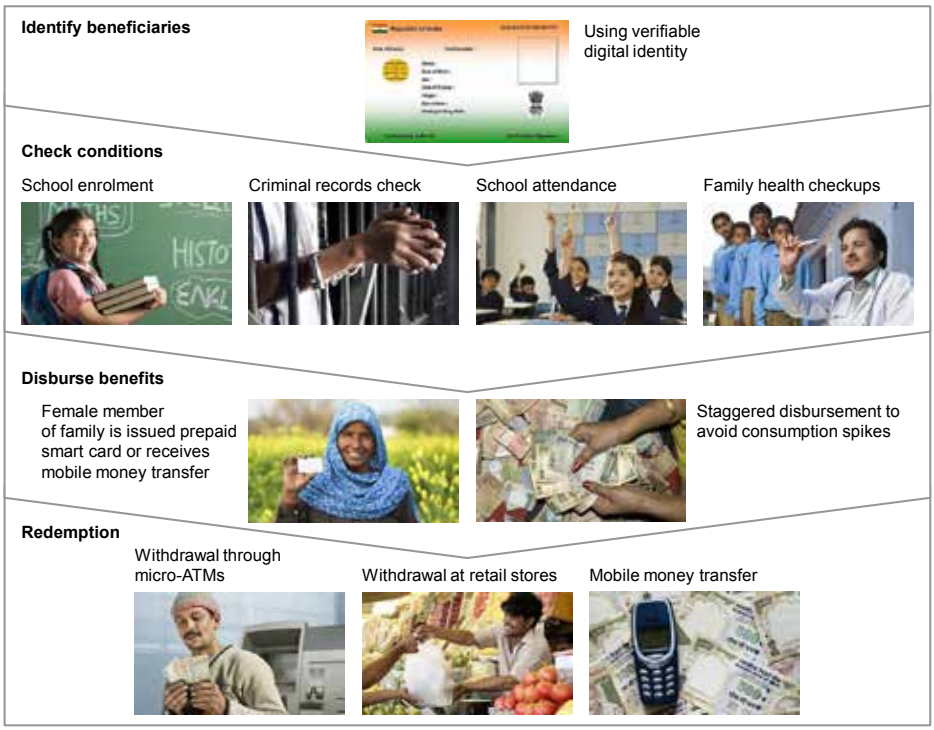
remittance services. The minimum capital requirement of such entities is only $10 million—one-tenth the requirement for a full-service bank. With lower costs, such payment banks could provide better compensation to correspondents who in turn would provide access to their services.

Digital government transfers and payments

India's government makes payments of about $100 billion per year to citizens: cash wages for work under employment guarantee programmes; bank, post office, and money order transfers to individuals (scholarships, pensions, and other allowances); and in-kind subsidies and services, which involve payments for goods at subsidised prices from government outlets. Each of these systems suffers from leakage and high administrative costs. As the universal electronic bank account programme brings more Indians into the banking system and payment points become ubiquitous, financial benefits that are now distributed in cash, cheques, and money orders can migrate to digital channels (Exhibit 14).[38] Digitisation of government payments and transfers could save interest cost, handling cost, and leakage, together the equivalent of 5 to 20 percent of the total annual flow. We estimate these applications have potential economic impact of $4 billion to $17 billion per year in 2025. This assumes that some 80 percent of the $175 billion of government spending on non-food basic services is channelled to government departments and agencies, external vendors, and consumers through digital channels.

Exhibit 14

Digital benefits transfers with mobile money can improve efficiency and reduce leakage



SOURCE: McKinsey Global Institute analysis

38 Digital transfers would be applicable for benefits flowing from government to citizens in financial form, i.e., they would exclude public distribution system of subsidised food grains, and benefits transferred in the form of health and education services.

Advanced credit underwriting

Providing access to formal credit is a challenge in places where people do not own homes, use credit cards, or have verifiable incomes. However, big data and advanced analytics techniques are changing underwriting, enabling the use of non-traditional data to assess creditworthiness. For example, bank underwriting systems today can look at mobile phone bills (with the subscriber's permission) and, based on how often and where a prepaid phone is topped up, draw inferences about the user's financial status. Several companies now specialise in underwriting using non-traditional data, targeting unserved customer segments in the United States and developing economies (Exhibit 15). Oi, a Brazilian telecom company, has scored credit for 2.7 million prepaid mobile customers in one of the poorest regions of Brazil. One universal bank in Central America is working with a supermarket chain to use transaction data (items bought, quantities, price, time of purchase, location, and mode of payment) from more than one million customers to identify "marker products" associated with high- and low-risk customers. This helps them augment credit-risk scoring and target customers for different types of loan products.

Exhibit 15

Big data–based underwriting tools are being used to extend credit

New initiatives in the United States

zest

Uses thousands of variables in combination with machine learning to develop multiple models that "vote" on whether to make a loan

Kreditech

Creates credit scores based on online behaviour, including location data, social network data, web surfing, e-commerce behaviour, and device used

Kabbage

Makes loans to small online sellers based on transaction patterns, UPS shipping data, and social network data, such as number of Twitter followers

New initiatives in emerging markets

M-Shwari

Credit and savings program built on M-Pesa in Kenya; underwrites using mobile calling, texting, and payments data; threat of cutting off mobile access in case of non-repayment

CAPITEC BANK

South African startup serving lower mass market (2.5 million customers); uses transaction habits of previously unbanked for underwriting

cignifi

Latin America–focused bureau for mobile operators creates credit and propensity-to-buy scores based on calling and texting patterns

SOURCE: Company websites; press articles; McKinsey Global Institute analysis

Today in India, there are just 160 million credit accounts, compared with 624 million savings accounts. We estimate that credit underwriting using unconventional data could enable lending of as much as $30 billion per year to unbanked and under-banked Indians by 2025. This assumes that consumer privacy concerns are addressed sufficiently and that consumers are willing to let their data be used for credit rating.

Enhanced customer experience

Around the world, banking services are reaching new levels of simplicity, personalisation, and customer engagement with the help of smartphones, intelligent interfaces that recognise speech, social technologies, and other

advances. Banks are making the customer experience simple, fun, convenient, and user-friendly. For example:

- Australia's Commonwealth Bank has developed an iPhone app that enables customers to take a picture of a property and find out if it is for sale, its sales history, and other market information. The app taps into databases with information on more than 95 percent of residential properties in Australia.

- La Caixa, a Spanish bank, has opened its own app store with more than 65 applications for account management, online transactions, investing, and credit-card personalisation. It even offers services such as bill paying that can be used by people without a La Caixa account. There is also a currency convertor and a "Learn to save" educational app for children. La Caixa's applications have been downloaded more than four million times.

- Simple is a free, by-invitation service in the United States that offers an FDIC-insured deposit account, a debit card, a range of smartphone tools, and access to customer service. A Simple account holder can deposit a cheque by phone by taking a picture of it and can instantly send money to other Simple account holders. Simple has more than 100,000 customers across the United States, a five-fold increase since the end of 2012.

- ASB, a New Zealand-based bank, offers a two-way, private, secure chat system with virtual agents in its virtual branch on Facebook.

These innovations could soon proliferate in India. About 7 to 10 percent of all bank customers in India use online banking, and the share is rising rapidly. In a McKinsey survey of Indian banking customers, most affluent customers (with incomes of $20,000 or more) stated that they rate flexibility, customisation, and distinctive user experience more highly than price when selecting a banking service. To expand the base of online banking customers, banks will have to adopt non-traditional thinking about customer experiences and borrow ideas from businesses that have engaged customers successfully on the Internet and social platforms.

Several banks in India have started experiments to improve the customer experience using technology. Kotak Mahindra Bank offers a mobile app that allows easy peer-to-peer money transfers. ICICI Bank has launched Pockets, a Facebook app that allows payments between Facebook friends. And HDFC Bank has launched Smartbuy, an e-commerce marketplace for customers of the bank.

Digitisation of sales and fulfilment

Advancements in technology can disrupt operations along the entire value chain for financial services players. In particular, technology is altering how financial services companies identify and target potential customers. Using big data analytics, financial services companies can combine proprietary data such as customer transaction histories and profile information with external data (with clear permission from consumers) to divide customers into micro-segments. Based on this segmentation, they can provide sales representatives with simple, targeted leads, allocated by geographic mapping, with clear recommendations for the most relevant products to promote or sales pitches to use. The conversion rate for such well-researched leads could be twice that of a cold call.[39]

39 McKinsey & Company research.

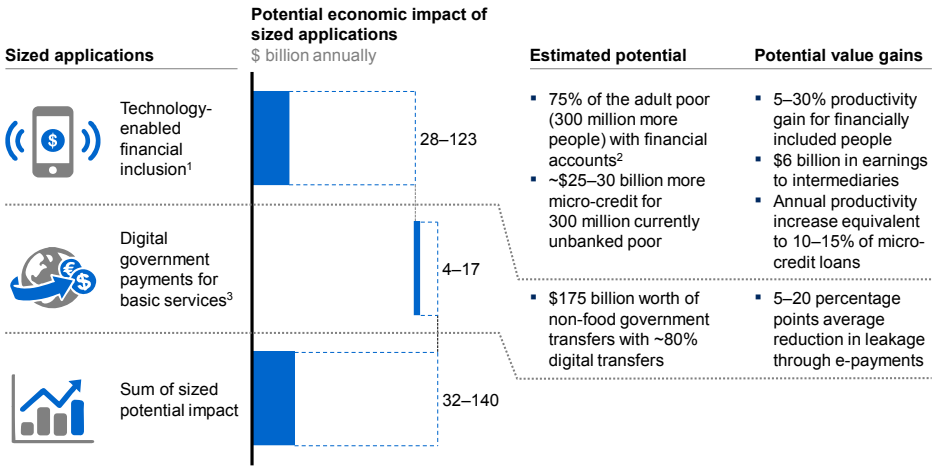
Disruptive technologies also enable a more engaging and useful sales process for customers, such as a graphical tool for financial goal management. These can be supported by videos, product comparisons, and interactive displays to address frequently asked questions. Finally, financial players can use technology to automate account openings and other transactions, now done on paper, to achieve instant (or nearly instant) fulfilment. In one bank, for example, complete digitisation of the mortgage origination process brought the approval time down from as much as ten days to 15 minutes, and reduced the bank's cost by 70 percent. An iPad-based system used by branch personnel at another bank reduced the time to open an account to five minutes, from one to five days.

POTENTIAL IMPACT

To estimate the economic impact of technology on the financial sector, we focus on the first five applications: universal electronic bank accounts, technology-enabled banking correspondents, mobile money, digital government transfers and payments, and advanced credit underwriting. We estimate that the economic impact of these technology-based services could be $32 billion to $140 billion per year in 2025 (Exhibit 16). This value arises from improved productivity and higher incomes of those using the services, and lower costs and leakages in government transfers and payments.

Exhibit 16

Selected technology applications in Indian financial services could have economic impact of $32 billion to $140 billion per year in 2025


Potential economic impact of sized applications
$ billion annually
Sized applications
Estimated potential
Potential value gains
Technology-enabled financial inclusion[1]
28–123
▪ 75% of the adult poor (300 million more people) with financial accounts[2]
▪ ~$25–30 billion more micro-credit for 300 million currently unbanked poor
▪ 5–30% productivity gain for financially included people
▪ $6 billion in earnings to intermediaries
▪ Annual productivity increase equivalent to 10–15% of micro-credit loans
Digital government payments for basic services[3]
4–17
▪ $175 billion worth of non-food government transfers with ~80% digital transfers
▪ 5–20 percentage points average reduction in leakage through e-payments
Sum of sized potential impact
32–140

1 Includes the impact of universal electronic bank accounts, technology-enabled business correspondents, mobile money, and advanced credit underwriting (for financially included households only).
2 Individuals over 18 with less than Rs. 200,000 in household income.
3 Includes the impact of digital payments by the government to consumers or vendors for health care, education, drinking water, sanitation, and energy subsidies, as well as employment guarantee programmes; impact of technology on government food programmes is captured separately in the chapter on agriculture.
NOTE: Estimates of potential economic impact are for some applications only and are not comprehensive estimates of total potential impact. Estimates include consumer surplus and cannot be related to potential company revenue, market size, or GDP impact. We do not size possible surplus shifts among companies and industries, or between companies and consumers. These estimates are not risk- or probability-adjusted. Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

Our estimates assume that 75 percent of India's adults with annual household incomes of less than Rs. 200,000 ($3,333) can gain access to banking services in 2025. We also assume that improved access to banking and innovations in underwriting through digital technologies can help more Indians qualify for credit, providing about $30 billion of new consumer loans in 2025. Based on experiences in nations such as Kenya, we estimate that improved access to banking and

credit services can lead to increases of 5 to 30 percent in the productivity and income of formerly unbanked consumers.

Financial inclusion could raise the number of electronic money transactions to one billion per day in 2025, creating additional economic value of at least $6 billion per year (on the basis of fees likely to be recovered by telecom companies and banks). Converting government payments to digital format can reduce handling costs, interest costs, and leakage by five to 20 percentage points of the annual flow. Finally, about one million to 1.5 million jobs could be created for technology-enabled financial agents or banking correspondents, providing basic financial services.

Beyond the economic impact, we anticipate that disruptive technologies can spur radically new business models in India's banking sector in the next decade, including the following:

- Widespread adoption of cloud storage that challenges the need for banks to invest in huge data warehouses.
- A combination of mobile money and near-field communication (the technology that enables transactions by placing one smartphone close to another) for payments, reducing the need for physical branches even in remote rural locations.
- Low-cost 3D printing that could allow customers to print personalised banking kits with ATM and credit cards at their homes.
- A change in standards that would allow chequing deposits from smartphones.

In an extreme scenario, the core business of banks could become one of branding and risk management, with most other traditional banking elements outsourced to technology service providers. While we do not size the economic impact of such a shift, we acknowledge the tremendous scope and scale of transformation that technology will drive in the financial sector.

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

Realising the full potential impact of these technology applications will require innovation by the financial services industry and regulatory support. The financial services industry is ready to harness the potential of technology. Now, government support will be needed. The government has made financial inclusion a priority and taken steps to bring the unbanked millions into the formal financial system. The adoption of regulations to make seamless the process of digital identity issuance and electronic bank-account opening will help accelerate this process. The emergence of an economically viable business model for payment banks would provide impetus for telecom companies and other non-bank players to compete for unbanked consumers and drive financial inclusion. Using Aadhaar-linked accounts and mobile payments for government payments can create more pull and stickiness for electronic banking services and raise the incomes of banking correspondents and mobile money providers. This would help create a mutually beneficial ecosystem for mobile money. Finally, a policy framework can be created to address security and privacy concerns in sharing unconventional data for credit underwriting.

3. Education and skills

As in other parts of the world, India is turning to digital technology to improve the quality of teaching and raise the capacity of its schools, universities, and vocational training institutions. Technology-based instruction and management systems promise to bring education and vocational training even to remote areas and improve the quality of teaching and the level of student achievement across the board. We estimate that adoption of empowering technologies in education and skill training can have an economic impact of $60 billion to $90 billion per year by 2025 in India. This value is based on the higher productivity and pay of workers with more years of schooling and job-specific skills training. By 2025, 24 million Indians could be better prepared for the kinds of jobs that are likely to be created, reducing India's potential skills mismatch.

CHALLENGES IN INDIAN EDUCATION

From elementary schools through university and vocational training, Indian education faces challenges of capacity and quality.

Weak school learning outcomes

In K–12 education, India has achieved near-universal primary school enrolment, but only 63 percent of students reach the secondary level (grade 10) and just 36 percent complete upper secondary school (grade 12). Dropout rates are high due to poor quality of education caused by factors such as inadequate teacher training and significant teacher absenteeism.[40] Students who do progress to upper grades often perform unfavourably compared with students around the world; India ranks 72 out of 73 nations in the Organisation for Economic Co-operation and Development's Programme for International Student Assessment (PISA) exams.[41] The K–12 system also suffers from weak student, teacher, and school assessment and monitoring processes and poorly trained administrators.

Low employability of workers with higher education

While India has an extensive system for higher education—the nation is projected to contribute 27 percent of the global growth in tertiary-educated workers between 2010 and 2030—quality is a problem.[42] The country's IT services industry still needs to invest in training for many graduates of Indian engineering and computer sciences colleges to make them job-ready, an indication of some of the challenges facing higher education in India. No Indian college is listed in the

40 India's Planning Commission notes that several states in the north, east, and northeast regions have an acute problem of untrained teachers. Teacher absenteeism runs as high as 15 to 42 percent, according to the World Bank; see F. Halsey Rogers and Emiliana Vega, *No more cutting class? Reducing teacher absence and providing incentives for performance*, World Bank policy research working paper number 4847, February 2009.

41 PISA evaluations were conducted in only two Indian states, Himachal Pradesh and Tamil Nadu, in 2009. India has opted out of the PISA evaluations to be conducted in 2015.

42 *The world at work: Jobs, pay, and skills for 3.5 billion people*, McKinsey Global Institute, June 2012.

QS World University Rankings of the world's top 200 universities, while Singapore and China both have two in the top 50 universities in the world and Hong Kong has three.

Large vocational training gap

Today, just about 10 percent of the Indian labour force has received formal or informal vocational training. This compares with over 95 percent in South Korea, 80 percent in Japan, 75 percent in Germany, and about 68 percent in the United Kingdom. In a McKinsey survey, 53 percent of employers in India said that lack of skills was a leading reason for entry-level vacancies; on average, 39 percent of respondents from eight countries cited lack of skills as a reason for not filling such positions.[43] India has the capacity to train about 20 percent of new workers entering the labour force each year. The National Council on Skill Development and the National Skill Development Corporation are working to expand skill development capacity by providing seed capital to private training firms, improve quality and standards, and develop certification frameworks. However, if current trends persist, the country is likely to have 30 million to 35 million more low-skill workers than employers will demand in 2020.[44]

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

Technology-based innovation in education can enable rapid and large-scale improvement in education and skills training and help prepare a productive workforce for India. Across K–12, higher education, and vocational training, eight technology-based innovations and services can transform India's education system (Exhibit 17).

All these applications are being deployed in advanced economies, and many are starting to be seen in India. They are enabled by a combination of broad-based technologies such as the mobile Internet, the cloud, and automation of knowledge work, and enabled by digital payments, verifiable digital identity, and advanced energy technologies that can provide uninterrupted power. Social technologies, "gamification", virtual reality technology, and collaboration tools are also being used in education and training to make these applications more compelling to users. Education can be transformed with the help of these technologies, with teachers, facilitators, and instructors delivering computer-based lessons and using technology to monitor and guide students, while also providing one-on-one assistance and making the personal connections that can be critical to learning.

43 *Education to employment: Designing a system that works*, McKinsey Center for Government, December 2012.

44 *The world at work: Jobs, pay, and skills for 3.5 billion people*, McKinsey Global Institute, June 2012.

Exhibit 17

Eight technology-based services can transform education in India

E-administration of educational institutions	Computerised admissions, fee and vendor payments, payroll, student performance tracking	**Verifiable digital identity attendance systems**	Attendance monitoring of teachers and students using biometric ID or smart cards
Tech-enabled teacher assessment, training, certification, collaboration	Automated performance tracking; cloud-based review, training, and certification; social platforms to share curricula and content	**Low-cost instructional devices**	Tablets and other inexpensive devices for instruction and content delivery
Adaptive learning	Instructional software that monitors progress through frequent assessments and tailors lessons and drills for individual students to ensure mastery of skills and content	**Blended learning with MOOCs**	Delivering MOOCs (massive open online courses) to classrooms with teachers to facilitate discussion and learning
Learning simulations for skills training	Simulations for hands-on training in nursing, business, and other disciplines using immersive learning software, virtual reality, dummies/machinery with sensors	**Labour portals**	Online platforms with job listings and requirements, market data, and career planning resources; employers use portals to recruit, and workers can post résumés and use portal information to make better-informed decisions (such as field of study)

SOURCE: McKinsey Global Institute analysis

E-administration

Automated administration systems can improve efficiency and stretch the capacity of administrative resources. Such systems capture data about student performance to provide real-time information for teachers and administrators to identify problem areas that need immediate attention. Schoolnet, for example, a system used by US school districts that have a total enrolment of five million students, collects student assessment data, analyses results, and reports findings to administrators, teachers, students, and parents. Schoolnet data are also used for teacher feedback and school performance ratings, and they help students plan their course of study.

E-administration is being used in developing economies, too. In Kenya, Bridge International Academies has created a low-cost "Academy-in-a-Box" application for school management that incorporates everything from mobile tuition payments to admissions and performance tracking, as well as curriculum materials (Exhibit 18). The for-profit company runs a network of more than 300 schools where nearly 100,000 students pay just $5 per month. The Bridge system standardises curricula and teaching across schools to remove variability and free up teacher and administrator time for work that requires personal interaction. In India, the Sampoorna online school management system has been used in Kerala to track the performance of six million students, saving 20 to 30 percent of teacher and administrator time. Kerala is one of the best-performing states in education.[45]

Exhibit 18

Academy-in-a-Box: A low-cost model for teaching and administration

Bridge International example

Cashless schools	E-administration	E-teaching apps	Online assessment
▪ M-Pesa mobile money or direct bank fee payment of fees ▪ Smartphone app for school manager to manage fee payments ▪ SMS system to coordinate with central office for teacher and vendor payments ▪ Cost savings: Only one non-teaching employee needed	▪ Admissions: Students apply and submit test scores by smartphone ▪ Teacher auditing and record-keeping enabled by smartphone ▪ Data capture: Monthly statistics on absences and late arrivals generated automatically ▪ Monthly assessment data sent to head office	▪ Tablets deliver scripted lessons and act as grade books ▪ Wi-Fi check-in for teachers; in case of absence, substitutes are automatically contacted ▪ Tracks teaching time spent on each lesson ▪ Allows low-skill teachers to teach effectively; efficient teacher training medium	▪ Oversight: Regular assessments of operations via smartphone app ▪ Controlled sampling by external assessment teams ▪ 24/7 call centre for pupils, parents, staff ▪ Results: reading scores 30–100% higher than in peer schools

SOURCE: Bridge International Academies website; Harvard Business School case study; McKinsey Global Institute analysis

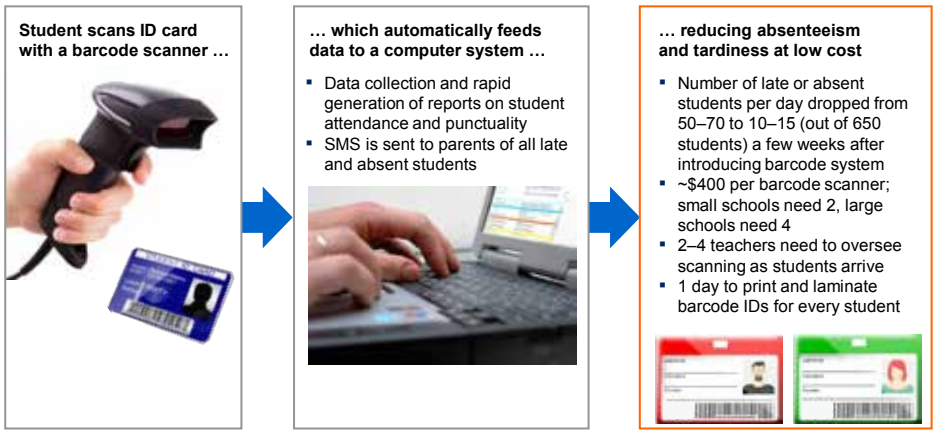
Verifiable digital identity attendance systems

Student and teacher absenteeism is a problem across India and across levels of education. A pilot in five government colleges in Bengaluru used a biometric attendance system with a smartphone app and a camera to record when teachers enter and exit classrooms. The device employs face recognition software and unique identity numbers to verify that the right teacher is in the right room for the right amount of time. In Bengaluru, teacher attendance improved, and the administration saved overhead costs that had been needed to maintain manual attendance records. The system has been rolled out to 47 polytechnics and engineering colleges around the state. In Bahrain and other places, barcode scanners are being used to monitor and improve student attendance (Exhibit 19). Schools in Singapore have installed fingerprint readers linked to an electronic attendance system, saving as much as 90 percent of the time needed for monitoring attendance.

45 *Annual status of education report (rural) 2012*, ASER Centre, January 2013.

Exhibit 19

Bahrain uses barcode scanners in student attendance


Student scans ID card with a barcode scanner …
… which automatically feeds data to a computer system …
Data collection and rapid generation of reports on student attendance and punctuality
SMS is sent to parents of all late and absent students
… reducing absenteeism and tardiness at low cost
Number of late or absent students per day dropped from 50–70 to 10–15 (out of 650 students) a few weeks after introducing barcode system
~$400 per barcode scanner; small schools need 2, large schools need 4
2–4 teachers need to oversee scanning as students arrive
1 day to print and laminate barcode IDs for every student

SOURCE: Expert interviews; McKinsey Global Institute analysis

Tech-enabled teacher assessment, training, certification, and collaboration

Improving the quality of education begins with improving teacher quality—by helping or eliminating poorly performing teachers and raising the skills of others. In addition to online teacher training and assessment, schools are using collaborative technology platforms to facilitate knowledge sharing and skill building among teachers. In the United States, for example, teachers in Boston and Atlanta launched a social platform called BetterLesson in which they share curricula and instructional resources. Teachers can upload and download instructional content and use a course-builder tool to organise teaching material. Edmodo, which provides a platform for teachers and students to collaborate, is used by more than 8.5 million teachers and students in more than 80,000 schools globally. The platform allows teachers to share content and manage homework, grades, discussions, and other classroom activities. Teachers can also connect to a global network of peers and pull down content and teaching applications.

In India, online teacher training and certification is a potentially powerful way to improve teaching quality. For example, a mandatory annual online refresher course would help a class 8 math teacher keep up with the latest tools and teaching techniques in the subject. The cost of building and staffing training schools to provide teacher training and certification in India would be prohibitive. A more efficient choice in India is e-learning modules and online assessments that lead to online certifications.

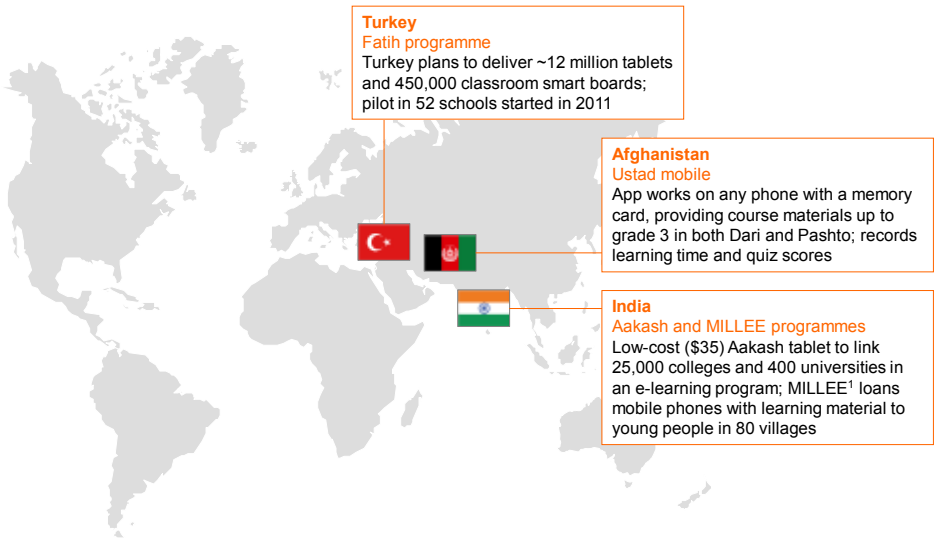
Low-cost instructional devices

India is among the developing economies working on ways to provide students with low-cost devices—smartphones or tablets—to deliver computer-based instruction (Exhibit 20). India announced plans to come up with the "Aakash" student tablet in 2011. The commercial version of the device, known as Ubislate 7+, is being sold for Rs. 4,000 ($65). The government's goal is to link 25,000 colleges and 400 universities in an e-learning programme enabled by affordable tablets and subsidised by the government.

Other low-cost approaches are being developed to bring computer-based instruction to classrooms. Zaya Labs, an Indian social enterprise, offers the "Labkit" to deliver its after-school supplemental instruction material for K–12 students. Each kit consists of a 3G WiFi router ("ClassCloud") with ten hours of battery power, pre-loaded content, a digital projector, and student tablets; the whole package fits in a backpack. Classes are run by franchisees who hold teaching groups in their homes, for a fee of $6 per month per child. K-Yan is a package developed by IL&FS Education and Technology Services to deliver interactive computer-based teaching to secondary school students. It combines a computer, flat-screen TV, pre-loaded content, DVD player, projector, and audio system. It can be used wherever there is a wall and Internet access.

Exhibit 20

Mobile devices are being used to deliver instruction across the developing world


Turkey
Fatih programme
Turkey plans to deliver ~12 million tablets and 450,000 classroom smart boards; pilot in 52 schools started in 2011
Afghanistan
Ustad mobile
App works on any phone with a memory card, providing course materials up to grade 3 in both Dari and Pashto; records learning time and quiz scores
India
Aakash and MILLEE programmes
Low-cost ($35) Aakash tablet to link 25,000 colleges and 400 universities in an e-learning program; MILLEE[1] loans mobile phones with learning material to young people in 80 villages

1 Mobile and Immersive Learning for Literacy in Emerging Economies.
SOURCE: Interviews; media search; McKinsey Global Institute analysis

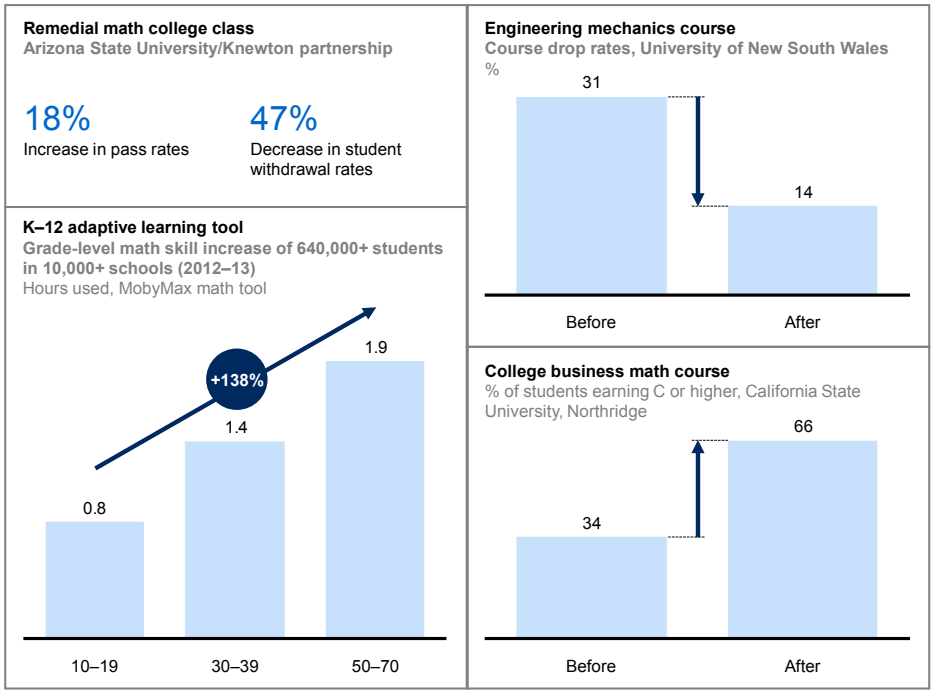
Adaptive learning

Adaptive learning systems aim to improve student performance by customising lessons to match each student's progress in mastering specific knowledge and skills. Students get lessons from the online system, which tracks how long it takes each student to complete the lesson and administers frequent assessments to determine if knowledge and skills have been acquired. In Carpe Diem charter schools in the United States, for example, students learn independently at their own pace, and teachers track progress using comprehensive digital records, assisting students when needed and leading group instruction and discussion. The company claims that in its Yuma, Arizona school, 92 percent of students achieved proficiency in math and reading assessments, compared with 60 to 70 percent at other schools. In higher education, companies such as Knewton, CogBooks, Smart Sparrow, and Cerego have instituted adaptive learning systems at colleges and universities such as Arizona State University.[46] These courses have had lower withdrawal rates and higher pass rates than conventional classes (Exhibit 21). In India, the Mindspark adaptive learning system is used by 50,000 K–12 students. In a pilot program in the Mumbai Municipal Schools, test scores improved by more than 34 percent after using the Mindspark system, according to the vendor.[47]

Exhibit 21

Impact of adaptive learning systems in schools and colleges

Examples



SOURCE: *Learning to adapt: A case for accelerating adaptive learning in higher education*, Education Growth Advisors, 2013; MobyMax adaptive learning tool; California State University Northridge Office of Institutional Research; McKinsey Global Institute analysis

46 *Learning to adapt: A case for accelerating adaptive learning in higher education*, Education Growth Advisors, 2014.

47 *A personalised adaptive learning system for students*, Educational Initiatives working paper series issue 3, 2009.

Blended learning with massive open online courses

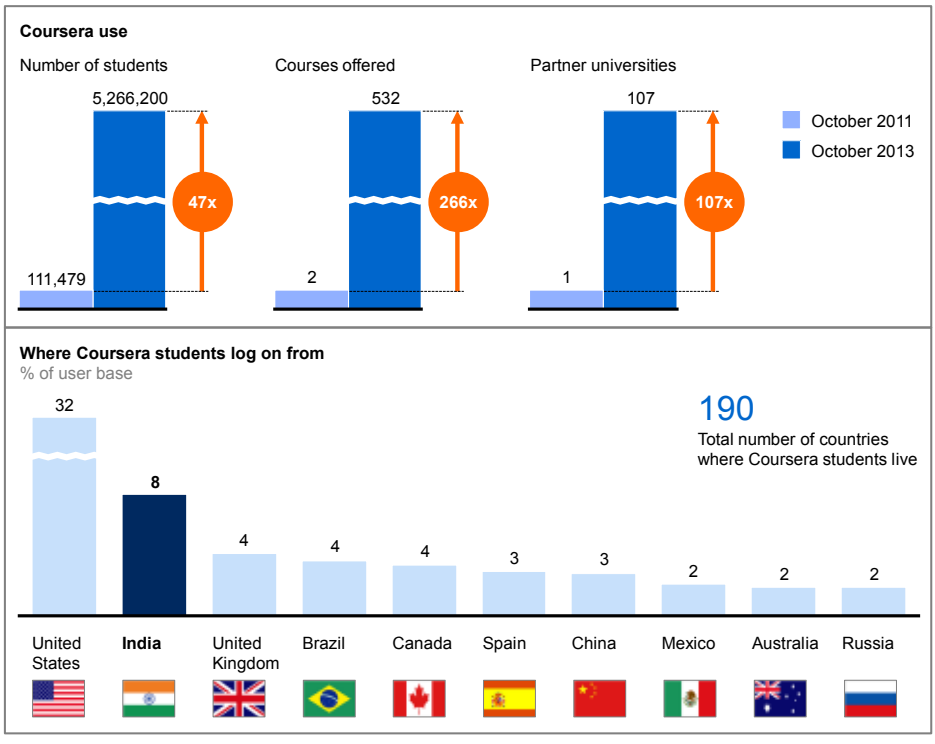
Online college courses have caught on around the world, and India is already the second-largest country of origin for participants in MOOCs (massive open online courses),, accounting for about one-tenth of the 8.6 million users of Coursera and edX in 2013 (Exhibit 22). While MOOCs have clearly tapped into unmet demand in India, course completion has been an issue. Globally, completion rates are estimated to be just 7 to 10 percent. Issues include lack of reliable Internet access in some countries (including India) and lack of interaction with peers, teachers, and facilitators. Pure online courses cannot wholly substitute for the role played by human interaction in the learning process, just as education itself cannot completely substitute for "learning by doing" in real-life work contexts.

Now, assisted or facilitated models are making MOOCs more useful. Students watch lectures online in advance, and professors use classroom time to discuss the material and work on problems. Another approach is Coursera Learning Hubs, a pilot programme that involves in-person sessions with expert facilitators. Sessions have been conducted at US embassies, consulates, and other public spaces in several countries, including India. In these sessions, facilitated Q&As and other interactions among participants augment the lecture. At Stanford University, MOOCs are being offered in parallel with on-campus classes. This allows Stanford students who could not get into oversubscribed classes to participate in the class along with thousands of students across the globe. In addition, Stanford students benefit from the insights of thousands of others who take the MOOC version of the class and submit their reports. Other universities are trying HOOCs, or hybrid open online courses, in which online students can listen in on campus-based seminars and participate in the discussion via Twitter.

Exhibit 22

Massive open online courses (MOOCs) are growing rapidly

Coursera example



SOURCE: Coursera; McKinsey Global Institute analysis

Learning simulations for skills training

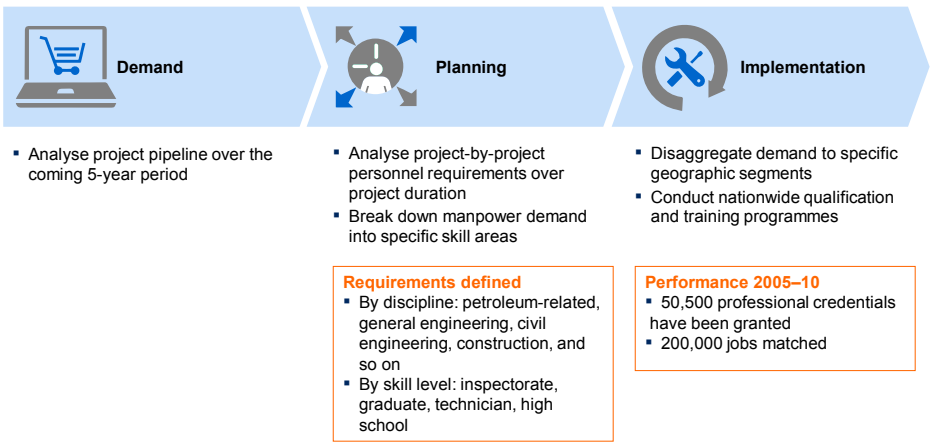
Simulated learning systems have the potential to help India close its skills-training gap, particularly in areas such as health care, manufacturing, and business management. Using immersive learning software, virtual reality displays, and motion sensors, a student can practise skills and be evaluated in a risk-free environment. Many hospitals in the United States and the United Kingdom use simulators (dummies with sensors) to teach procedures for diagnosis, emergency room care, and surgery. Realityworks and IBM provide simulated e-learning in areas such as business management and entrepreneurship, urban planning, welding (using fully functional, computer-enabled tools), and even infant care, with simulated babies that record data to assess the quality of care being provided.

Labour portals

Matching workers with jobs is an important component of an education and training strategy. Around the world, nations are investing in online labour portals to make job markets transparent to applicants and help students select majors and courses to fit employer needs. The UK National Careers Service provides a combination of online offerings—a labour market database, career planning tools (such as a résumé builder)—as well as a help desk with 350 career advisers. The Labour Market Information Portal in Australia lists local job requirements, employment opportunities by specific skills and skill levels, wages for different jobs, and detailed data on vacancies for 350 occupations (at all skill levels), as well as openings in all states, territories, and regions. The Brazilian Prominp system provides detailed national hiring plans by oil companies, broken down by discipline, skill level, and region, and it provides qualification and training (Exhibit 23). In 2011, India's National Skill Development Council outlined a plan to set up a labour market information system that sector skills councils are expected to implement.

Exhibit 23

Brazil's Prominp portal projects oil crew needs based on upcoming projects and provides credentials


Demand
Planning
Implementation
Analyse project pipeline over the coming 5-year period
Analyse project-by-project personnel requirements over project duration
Break down manpower demand into specific skill areas
Disaggregate demand to specific geographic segments
Conduct nationwide qualification and training programmes
Requirements defined
By discipline: petroleum-related, general engineering, civil engineering, construction, and so on
By skill level: inspectorate, graduate, technician, high school
Performance 2005–10
50,500 professional credentials have been granted
200,000 jobs matched

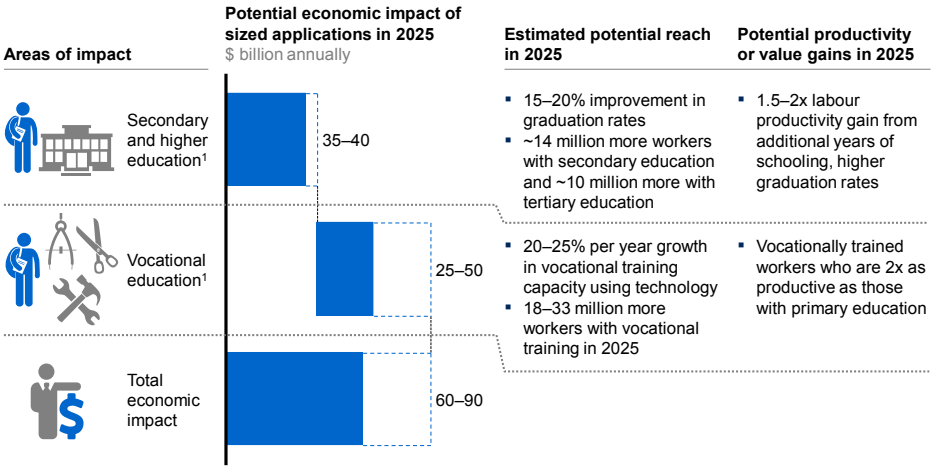
SOURCE: O&G Brazilian Industry Mobilisation Programme presentation, Prominp, 2009; McKinsey Global Institute analysis

POTENTIAL IMPACT

The potential economic impact of technology to improve educational outcomes is large and widespread. If technology is adopted in India's schools, colleges, and vocational training institutes along the themes outlined above, the incremental economic impact could be $60 billion to $90 billion per year by 2025 (Exhibit 24).

Exhibit 24

Selected technology applications across Indian education can have economic impact of $60 billion to $90 billion per year in 2025


Areas of impact
Potential economic impact of sized applications in 2025
$ billion annually
Estimated potential reach in 2025
Potential productivity or value gains in 2025
Secondary and higher education[1]
35–40
▪ 15–20% improvement in graduation rates
▪ ~14 million more workers with secondary education and ~10 million more with tertiary education
▪ 1.5–2x labour productivity gain from additional years of schooling, higher graduation rates
Vocational education[1]
25–50
▪ 20–25% per year growth in vocational training capacity using technology
▪ 18–33 million more workers with vocational training in 2025
▪ Vocationally trained workers who are 2x as productive as those with primary education
Total economic impact
60–90

1 Includes the integrated impact of technology-enabled educational systems and devices.
NOTE: Estimates of potential economic impact are for some applications only and are not comprehensive estimates of total potential impact. Estimates include consumer surplus and cannot be related to potential company revenue, market size, or GDP impact. We do not size possible surplus shifts among companies and industries, or between companies and consumers. These estimates are not risk- or probability-adjusted. Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

A major source of this value would be reducing dropout rates and getting more students to complete more years of education. Based on current trends, an estimated 14 million workers with no education or just primary schooling, and 51 million workers with secondary education (but no tertiary education) will join India's labour force by 2025.[48] If all the technology initiatives described in this chapter are successfully implemented, retention rates in primary and secondary schools would improve, which could mean that all of the estimated 14 million workers who would have entered the labour force with only a primary education or less would have at least a secondary education, and an estimated 20 percent of the 51 million workers who would have had only high school educations would receive some college education. This could mean that some 14 million to 24 million more workers in 2025 would have additional educational attainment, implying potentially higher productivity. Virtually all those passing through the school and college system in the coming decade—some 100 million students—would benefit from higher learning outcomes. The effect of bringing this many workers with higher educational attainment into the labour force could result in productivity gains of about $35 billion to $40 billion per year in 2025.

In vocational training, we expect that technology applications can help raise the annual growth rate of capacity by 20 to 25 percent, potentially providing training to 18 million to 33 million more workers by 2025. This would translate to productivity gains of $25 billion to $50 billion per year by 2025.

48 *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

Despite the clear benefits of new delivery methods for education enabled by technology and the enthusiasm with which schools and colleges are attempting to integrate computer-based education into their curricula, there are barriers to success. Individual institutions in India have limited flexibility to innovate because of government curriculum guidelines and rules for examinations and assessments. Low-income schools have physical limitations such as lack of power and classroom space. Even modern government schools have limited access to digital technology (broadband connections), and few education officials, teachers, and school administrators are fluent in technology. Finally, few technology providers can customise their offerings to suit the varying needs of schools in different states or in different economic environments.

Even where there is faster adoption of technology in India's education sector at present (for instance, in the urban private sector and higher income schooling segments), its utility is limited by insufficient customisation of technology to the local context and drivers of quality. Hybrid models that combine the strengths of teachers with technology are required to capture the full value of technology in education. And technology adoption has focused on core pedagogical uses (content and instruction), but not sufficiently on tracking and administrative applications (such as such as assessment analytics in K–12 and labour market matching in vocational education).

India urgently needs a multi-stakeholder programme for the technology-enabled transformation of education. This could bring together the government, education NGOs, foundations and funding agencies, IT industry associations, and project implementation experts to plan for more widespread technology adoption and disruption to traditional teaching and school administration methods. In many parts of the country, the effort must start with the basics—solar power and battery storage for stable electricity supply, waterproof and secure environments, basic tablets or computers, and training in how to use them.

In vocational training, the government, employers, and technology providers can develop IT-enabled certification system for skills providers, with a clear focus on measurable outcomes such as job placements and student satisfaction. This could be structured as a public-private partnership, managed by an independent, professional organisation. Vouchers could be used to help informal workers and the self-employed to upgrade their skills in certified vocational training programmes. India's employment exchanges can be repositioned as labour portals, with a clear mandate to match jobs with skills.

4. Health care

With India's enormous population, high rates of poverty, and limited resources, the health-care system is hard-pressed to serve the Indian people. Millions of poor Indians lack access to clean water and fall prey to waterborne disease, while rates of non-communicable diseases such as cancer and diabetes are also rising. Against these challenges, India has inadequate health-care infrastructure and a shortage of human resources; it has trouble treating the seriously ill and has little chance to provide preventive care. We identify nine empowering technology applications that can disrupt Indian health care, extending care to more citizens, improving quality of care, and reducing the cost of care. These range from remote health services that take advantage of mobile communication, to emerging technologies such as advanced genomics, which promise better results through customised, targeted medicines for individual patients. We estimate that these technologies together could create $25 billion to $65 billion a year in economic value in 2025. On top of this would be the incalculable blessings of less disease, more live births and surviving infants, fewer deaths per year, and longer life spans.

CHALLENGES FACED

Today, India's health-care system struggles to meet the needs of its citizens, and that challenge will only grow larger in the next decade. Public-sector efforts to boost health care have gained momentum in the past decade, following India's commitment to pursue the United Nations Millennium Development Goals. The government set targets to reduce the maternal mortality rate by three-quarters from 1990 to 2015 and to reverse the spread of HIV/AIDS, malaria, and other major diseases by 2015. Despite substantial efforts, however, India today seems likely to fall short of meeting Millennium Development Goals targets by 2015. Meanwhile, the burden of non-communicable diseases is growing. Of India's ten million deaths each year, about half are from chronic diseases such as diabetes, which require intensive and costly ongoing care.

Insufficient health-care resources

India's public spending on health care was only about 1 percent of GDP in 2010, less than a third of what Mexico, South Africa, and Brazil spend. About 70 percent of health-care spending is funded by households—and half of that is by the richest 20 percent of households.[49] While enrolment in the government-sponsored health insurance plan has grown, it covered just over 25 percent of the population in 2010. This means that many Indians simply go without insurance and risk financial disaster: it is not uncommon for medical emergencies to push families back into extreme poverty.

49 Ministry of Health and Family Welfare and NSSO household consumption survey 66th round (2010).

Inadequate funding leads to inadequate facilities. India had just 1.3 hospital beds per thousand people in 2010, and in rural India there were only 0.3 hospital beds. The standard recommended by the World Health Organization is 3.5 beds per thousand. Even where adequate health-care facilities exist, quality of care can be inadequate due to high staff absenteeism and a lack of standard diagnosis and treatment procedures.

India also has too few health-care workers—1.9 per 1,000 people, compared with 2.8 in China and 3.7 in Malaysia. Some 36 percent of India's qualified doctors and nurses are not working in the field, so the ratio of practicing doctors and nurses has fallen to 1.4 per 1,000, far below the World Health Organization norm of 2.5.[50] India has a large pool of AYUSH (Ayurvedic, Unani, and homeopathic or traditional forms of medicine) practitioners, but they are not adequately trained in allopathic (mainstream medical) procedures, and their methods are not universally accepted by medical professionals and patients.

Limited effectiveness of public health services

Poor access to clean drinking water and decent sanitation contributes to health complications, particularly in rural India. One in four rural families across India draws water from untreated taps and uncovered wells.[51] Poor-quality water can cause illness, and insufficient monitoring of water quality can lead to outbreaks before citizens are aware of any risk. Diarrhoeal diseases, for instance, account for one in six deaths annually among Indian children.[52] India's government spent Rs. 118,000 crore ($25 billion) on health care, water, and sanitation in 2012. However, we estimate that just 36 percent of public spending on health services translates into real health outcomes. In other words, health outcomes could be more than twice as good with the same level of spending.[53]

The infrastructure gap is serious, but with adequate funding and execution capability, it can be bridged. The task of filling the human resource gap will be more complex and time-consuming. Today, it takes two to three years to approve, build, and commence the operations of a well-functioning medical college, even assuming breakneck speed of execution. Then it would take six years before the first physicians graduate. It would take one to two years to set up a nursing college and three more years for the first trained nurses to graduate. In other words, if India had the resources to build all the medical and nursing schools it needs to fill the current talent shortage, it would still be a decade before the flow of new health-care professionals into the system, by which time the dimensions of India's health-care problem would have grown larger, with an expanding population during another decade of inadequate care. Clearly there are enormous needs for improvement across the Indian health-care system, and, we believe, the empowering technologies for India can play a very large role in addressing those needs.

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50 *World Health Statistics, 2011*, World Health Organization; *World Development Indicators 2010*, World Bank; *High level group report on universal health coverage for India*, Planning Commission of India, 2011.

51 *Census of India 2011*, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, Government of India.

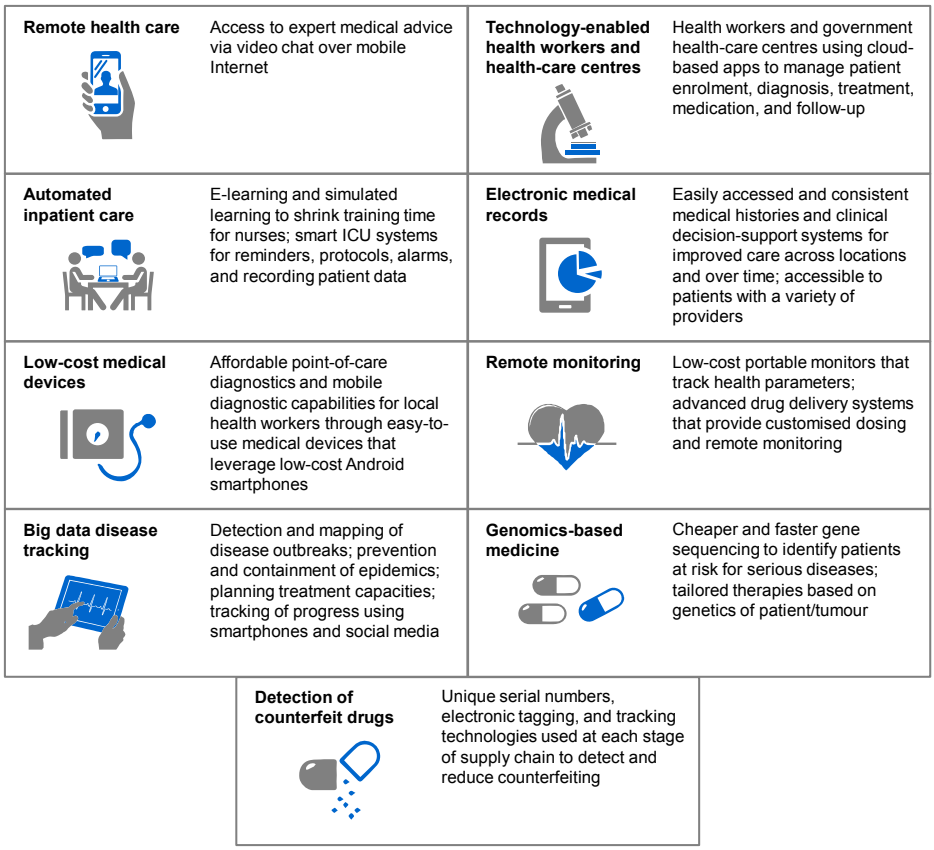
52 Integrated Management Information System reports of the Ministry of Drinking Water and Sanitation, Government of India, December 2013.

53 See *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

We highlight nine technology interventions that could transform health care in India within a decade by expanding reach, reducing cost, and improving quality (Exhibit 25). There are, of course, many more applications of these technologies in the health-care sector; the ones we highlight have the widest potential scope and can help solve India's particular challenges at this time.

Exhibit 25
Nine technology-based services can transform health care in India


Remote health care
Access to expert medical advice via video chat over mobile Internet
Technology-enabled health workers and health-care centres
Health workers and government health-care centres using cloud-based apps to manage patient enrolment, diagnosis, treatment, medication, and follow-up
Automated inpatient care
E-learning and simulated learning to shrink training time for nurses; smart ICU systems for reminders, protocols, alarms, and recording patient data
Electronic medical records
Easily accessed and consistent medical histories and clinical decision-support systems for improved care across locations and over time; accessible to patients with a variety of providers
Low-cost medical devices
Affordable point-of-care diagnostics and mobile diagnostic capabilities for local health workers through easy-to-use medical devices that leverage low-cost Android smartphones
Remote monitoring
Low-cost portable monitors that track health parameters; advanced drug delivery systems that provide customised dosing and remote monitoring
Big data disease tracking
Detection and mapping of disease outbreaks; prevention and containment of epidemics; planning treatment capacities; tracking of progress using smartphones and social media
Genomics-based medicine
Cheaper and faster gene sequencing to identify patients at risk for serious diseases; tailored therapies based on genetics of patient/tumour
Detection of counterfeit drugs
Unique serial numbers, electronic tagging, and tracking technologies used at each stage of supply chain to detect and reduce counterfeiting

SOURCE: McKinsey Global Institute analysis

Remote health care

Mobile technologies can bring expert medical advice to remote locations where medical practitioners are scarce while helping to improve the utilisation rate of urban doctors.

The mobile internet supports video consultations between doctors and patients or between doctors and local health workers attending patients with off-the-shelf applications such as FaceTime and Skype. In remote Andhra Pradesh, Health Management and Research Institute, a non-profit organisation, provides an Internet-based video chatting system that allows pregnant women to consult obstetrician/gynaecologists in Hyderabad city. A community health worker joins the expectant mother for the call and helps the patient carry out the doctor's instructions. The system has helped raise the rate of safe hospital or clinic deliveries by 50 percent. Technology-equipped government primary health centres and subcentres could perform similar functions. Each health centre

would have a health worker facilitating video-based interactions between patients and remote doctors (Exhibit 26). They could also be equipped with low-cost diagnostic devices to provide care services screening for anaemia or cataracts.

Exhibit 26
Potential remote health care models

SOURCE: Public Health Foundation of India; expert interviews; Jenara Nerenberg, "Procter & Gamble partners with Indian startup to deliver health care to the next billion consumers", *Fast Company*, November 9, 2010; McKinsey Global Institute analysis

Remote medicine need not be high-tech. In Mexico, Medicall Home provides hotline-based medical services to more than seven million individuals. A team of about 90 qualified doctors answers more than one million calls every year. Medicall has a protocol-based system that guides the doctors fielding the calls through standard procedures; fees are charged to the caller's mobile phone account. The service can also dispatch doctors for home visits or arrange ambulance services, both at discounted rates. The system has a referral network of 6,000 physicians and 3,500 health-service providers. In India, Fortis and HealthFore (formerly Religare Technologies), along with telecom provider Airtel, have launched Mediphone, a health-advice line that costs as little as Rs. 35 (just over 5 cents) per consultation.

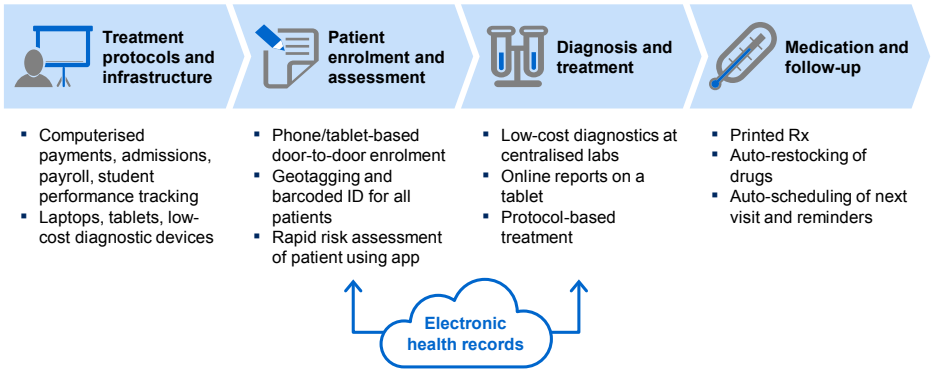
Technology-enabled health workers and health-care centres

With the proper technology, community health workers with modest skills and brief training can deliver some health services. Tamil Nadu health-care provider SughaVazhvu has equipped health extension workers with low-cost devices to access a cloud-based health management information system and render simple primary care (Exhibit 27). The worker records patient data (such as weight, height, and age), as well as global positioning system (GPS) location and basic household and demographic information. Each patient gets a barcoded identity card and a unique electronic patient record. The system records vital statistics and diagnostic information, conducts rapid risk assessment, supports protocol-based treatment, and schedules follow-up visits. It also manages drug shipments, human resource planning and training, and community disease mapping. Workers can be trained to use the system in eight to 12 weeks. With its system, SughaVazhvu provides health care through a network of non-traditional health practitioners and extension workers and has treated more than 100,000 patients. OpAsha, a large-scale program to combat multi-drug–resistant tuberculosis, uses an eCompliance tracking system to verify patient enrolment and treatment against records from government labs, hospitals, and medicine warehouses, and uses a portable biometric identification system to track whether the patient has received a dose of medication. The program also monitors follow-up.

Exhibit 27

Affordable community health care using health workers equipped with tablet computers

IT-enabled health-care delivery system by SughaVazhvu in rural Tamil Nadu


Treatment protocols and infrastructure
Patient enrolment and assessment
Diagnosis and treatment
Medication and follow-up
Computerised payments, admissions, payroll, student performance tracking
Laptops, tablets, low-cost diagnostic devices
Phone/tablet-based door-to-door enrolment
Geotagging and barcoded ID for all patients
Rapid risk assessment of patient using app
Low-cost diagnostics at centralised labs
Online reports on a tablet
Protocol-based treatment
Printed Rx
Auto-restocking of drugs
Auto-scheduling of next visit and reminders
Electronic health records

SOURCE: SughaVazhvu expert interviews; McKinsey Global Institute analysis

Automated inpatient care

Advanced computing power and intelligent systems (the kind of software being used to automate knowledge work) make medical care more effective by finding patterns in data that humans cannot detect, including discovering, across thousands of case records, which therapies have worked best for which kinds of patients. At Memorial Sloan Kettering Cancer Center in New York, doctors are pushing the envelope in this area with IBM's Watson supercomputer, which crunches data from 600,000 medical evidence reports, two million pages of medical journal text, and 1.5 million patient records and clinical trials to assist in diagnosing and recommending treatment based on proven results.

In the near term, expert medical systems are being used to help fill the human-resource gap. It takes ten to 15 years of experience for a nurse to acquire the skills to work in an intensive care unit. Through e-learning and simulated learning based on the expert knowledge of qualified ER nurses, skills can be quickly acquired. Smart ICU systems—specially programmed computers—can free up nursing capacity by taking on routine work of nurses such as recording patient data, setting protocols for diagnostic tests, raising alarms, and scheduling tasks for other staff. The system is much less prone to error and has led to a 60 to 80 percent reduction in nursing time taken for such tasks.[54] Using technology to raise nursing skills can help increase ICU bed capacity and offer more opportunities for highly trained doctors, such as interventional cardiologists, who otherwise are constrained by lack of ICU bed capacity.

Electronic medical records

Electronic medical records streamline processes in care settings because patient histories are available and up to date. In addition, aggregated data from the records of many patients can provide physicians with insights into which treatments work best for specific patient populations, eliminating variation and time lost by using less-effective methods. Used correctly, the records can also prevent potentially fatal errors, such as prescribing drugs that would have dangerous interactions, and can save costs by avoiding unnecessary or duplicative tests and procedures. In India, we estimate that more than 100 million redundant tests are ordered very year. One hospital used electronic medical record data to screen patients for risk of pulmonary embolism, based on specific physical parameters and risk factors that showed up in the data. Now, when an at-risk patient is identified, the physician is alerted, in effect raising the screening and treatment rate from 30 to 40 percent to 100 percent for the patients most likely to have an embolism. India is just beginning to adopt electronic medical record systems. In 2013, the government approved a framework for universal standards and interoperability to enable data sharing and analysis of electronic records. Full adoption will require a considerable effort to educate patients, medical professionals, and operators of hospitals, and clinics about the benefits of electronic medical records.

Low-cost medical devices

Low-cost mobile devices such as tablets and smartphones could have enormous impact on improving access to health-care diagnostics in India. The Public Health Foundation, a public-private initiative to improve health services is developing a device called the Swasthya Slate (health slate), which is expected to cost $250 to $300 and administer 33 diagnostic tests, including electrocardiograms. The unit attaches to any Android device programmed with decision-support tools that walk the health worker through a set of protocols and, based on results, advises if a doctor visit is recommended. Medical records are stored on a tablet device, phone, or cloud-based server. Swasthya Slate has been tested in 80 locations worldwide on more than 40,000 patients. It can help with early diagnosis of cardiovascular diseases such as hypertension, which the World Health Organization estimated led to 28 percent of India's ten million deaths in 2008.

54 Expert interviews; McKinsey Global Institute analysis.

India's Health Management and Research Institute has developed its own low-cost device called Dox-in-Box that is designed for use by travelling health workers in rugged terrains. It can take readings of eight vital signs, including heart and lung functions, blood pressure, and blood glucose levels, which are read by remote physicians. Netra, a $2 clip-on device that fits over the display screen of a smartphone and can diagnose eye conditions, was developed at the Massachusetts Institute of Technology. It vastly reduces the cost of eye tests and makes it possible to test patients for vision problems virtually anywhere (Exhibit 28)[55]. With smartphones becoming ubiquitous in India, low-cost diagnostics can be brought directly to hundreds of millions of people who have limited access to health care.

Exhibit 28
Low-cost medical diagnostic tools using smartphones

Netra example

- Cheap, portable eye testing device from MIT
- World's first smartphone diagnostic tool for the human eye
- Can measure farsightedness, nearsightedness, misshaped eye, age-related blurriness, and pupillary distance
- Almost 20,000 tests conducted worldwide; commercial launch expected

Benefits over conventional technology

Affordability	▪ Requires only a smartphone and a plastic lens attachment that costs about $2 ▪ Much cheaper than conventional equipment
Accuracy	▪ As accurate as $45,000 autorefractor ▪ Smartphone camera has resolution comparable to that of optometric devices
Ease of use	▪ Patient looks through lens, clicks a few buttons, has results in less than 3 minutes ▪ No need for training; patient is asked to complete a simple alignment task
Anywhere	▪ Works wherever people have a smartphone and can download the Netra app
Analysis	▪ Analytics software picks up patterns in eyesight (such as extent of vision, physical impairment) and suggests specific solutions

SOURCE: EyeNetra.com; expert interviews; http://web.media.mit.edu/~pamplona/NETRA/; McKinsey Global Institute analysis

Remote monitoring

One of the most promising uses of technology is to monitor patients remotely to help manage chronic diseases and avoid hospitalisations. Wrist monitors from Basis, Jawbone, and other suppliers have sensors that automatically monitor blood flow, temperature, and sleep patterns. With data from users, they can monitor eating habits, too. In the future, wearable monitors will also include electrocardiogram and electroencephalography capabilities and, via mobile phone or a computer, will alert physicians or paramedics when dangerous readings are recorded (Exhibit 29). Such systems might even be linked to advanced drug delivery systems to dispense medication before emergency personnel can arrive. Blood glucose testers and activity monitors can help diabetes management by calculating and dispensing precise insulin doses that can be delivered through insulin pumps. Monitors can also help improve the productivity of home health workers, who can focus on nutrition, hygiene, and physiotherapy, rather than taking readings. Medical interventions by home health-care workers would

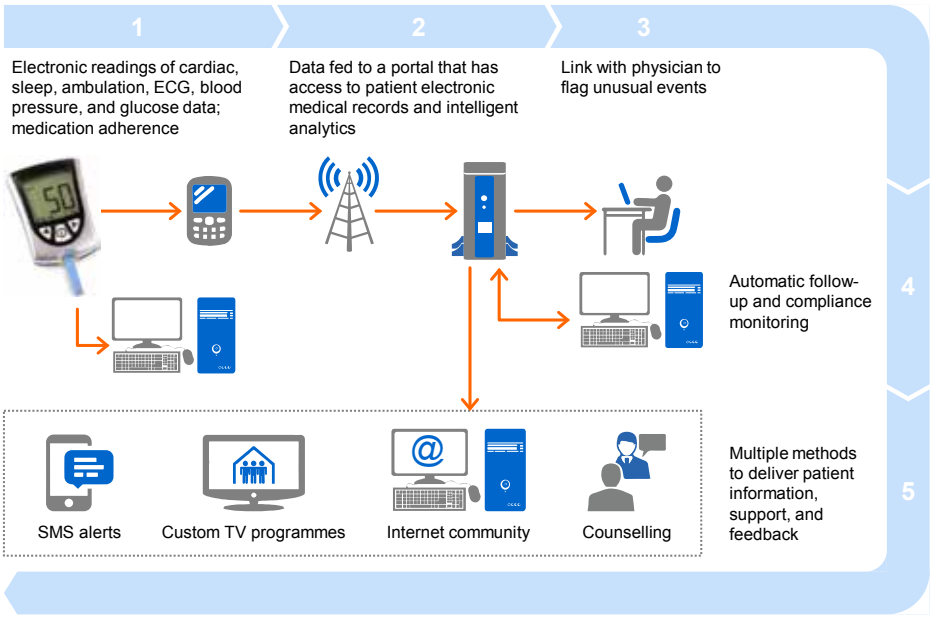
55 Vitor F. Pamplona, Ankit Mohan, Manurel M. Oliveira, and Ramesh Raskar, "NETRA: Interactive display for estimating refractive errors and focal range", *ACM Transactions on Graphics*, Vol. 29, Issue 4, July 2010.

also be more reliably monitored by intelligent systems, in conjunction with remote doctors.

Exhibit 29

Low-cost technologies make in-home remote patient monitoring practical

Integrated remote health monitoring concept


1
2
3
Electronic readings of cardiac, sleep, ambulation, ECG, blood pressure, and glucose data; medication adherence
Data fed to a portal that has access to patient electronic medical records and intelligent analytics
Link with physician to flag unusual events
Automatic follow-up and compliance monitoring
4
SMS alerts
Custom TV programmes
Internet community
Counselling
Multiple methods to deliver patient information, support, and feedback
5

SOURCE: Berg Insight; Disease Management Purchasing Consortium; McKinsey Global Institute analysis

Big data disease tracking

By applying advanced geospatial information systems along with big data analytics, public health services can track the spread of infectious diseases and devise effective strategies to deal with them. Google Flu Trends, for instance, predicts outbreaks by counting the number of flu-related Internet searches across the United States. Google's data have compared well against official influenza surveillance data and can complement traditional flu monitoring methods by providing daily updates (for some countries and regions).[56] To track flu outbreaks and plan treatment capacities in different parts of the country, the US Centers for Disease Control and Prevention mines data on pharmacy purchases, commuting traffic, and school attendance.[57] In the Punjab Province of Pakistan, big data analytics are helping prevent dengue epidemics by quickly identifying mosquito breeding grounds associated with new cases (Exhibit 30). Government officers on the ground use smartphones to photograph and geotag breeding areas.

56 Jeremy Ginsberg et al., "Detecting influenza epidemics using search engine query data", *Nature*, volume 457, number 7232, February 2009.

57 Alex Pentland, Todd G. Reid, and Tracy Heibeck, *Revolutionizing medicine and public health*, Report of the Big Data and Health Working Group, presented at the World Innovation Summit for Health in Doha, Qatar, December 10–11, 2013.

Exhibit 30

Big data–based disease surveillance is being used to manage epidemics

Dengue activity tracking portal

Google Play app for dengue tracking

How the tracking system works

- Field reports on location and timing of confirmed dengue cases and mosquito larvae sent via Android phone
- Each case tagged by time and location
- Source of infection identified and nearby mosquito breeding hot spots located
- Teams deployed to exterminate in outbreak areas
- Photos of pre- and post-extermination activity geotagged with spatial coordinates and transferred to database
- Automated analysis generates performance reports on a dashboard

SOURCE: *MIT Technology Review*; Google Play; McKinsey Global Institute analysis

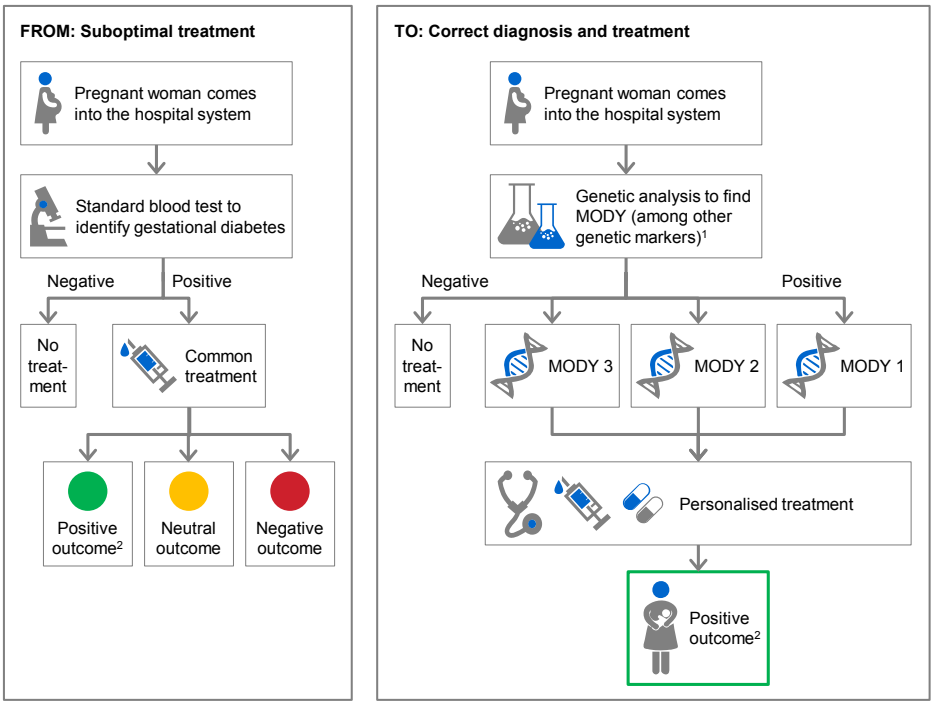
Genomics-based medicine

Cheaper and faster gene sequencing is making possible new treatments and therapies for chronic diseases. It is being used, for example, to screen pregnant women for gestational diabetes, allowing earlier, more effective intervention (Exhibit 31). Advanced genomics also enable personalised medicine—drugs that are customised for a particular patient or even a specific cancerous tumour. Advanced genomics are just coming into use in medicine in developed economies and are at a very early stage in India. A leading US cancer institute is collaborating with a group of Indian oncology centres to provide advanced molecular diagnostics and genomics testing. DNA samples from the Indian cancer patients are sent to the institute's US laboratory to identify mutations in cancer genes, which can be used to design treatment targeted to the specific tumour. Mapmygenome, an Indian startup, offers genetic diagnostics and counselling services for expectant parents based on genotyping.

Exhibit 31

Medical treatment can be customised based on advanced genomics

Gestational diabetes example



1 Maturity Onset Diabetes of the Young.
2 Positive outcomes defined as increased drug efficacy and/or reduced side effects; negative outcomes defined as decreased drug efficacy and/or increased side effects.
SOURCE: Expert interviews; McKinsey Global Institute analysis

Detection of counterfeit drugs

Interpol, the international police agency, estimated in 2013 that around the world one million people die each year from counterfeit drugs and that up to 30 percent of drugs sold in some areas of Asia, Africa, and Latin America are counterfeit. There are no reliable estimates of the scale of counterfeit drugs in India, but according to one study, between 5 and 12 percent of drugs sold by pharmacies in certain Indian cities were substandard.[58] The Federation of Indian Chambers of Commerce and Industry estimated in a 2009 report that 5 percent of drugs sold in India are counterfeit; that year, a government study put the figure at less than 1 percent through retail pharmacies.[59] Distribution of counterfeit drugs in poorer and less well-monitored parts of the country could be significantly higher than the national average.

The cost of substandard and counterfeit drugs in India is significant: between $600 million and $1.4 billion in lost sales in 2012, assuming a 5 to 12 percent market share for counterfeits. If that rate of counterfeiting remains stable and pharmaceutical sales stay on their current growth trajectory, the cost could be $3 billion to $7 billion by 2025.

58 Roger Bate et al., *A safe medicines chest for the world: Preventing substandard products from tainting India's pharmaceuticals*, International Policy Network, May 2010.

59 *Report on countrywide study for spurious drugs*, Ministry of Health and Family Welfare, Government of India, 2009.

Several countries are adopting track-and-trace packaging to ensure that packages are not counterfeits. Turkey has mandated unique serial numbers and tracking procedures at the unit level using barcodes. Producers, distributors, and retailers are required to upload product data to a central database managed by the Ministry of Health, and pharmacists who dispense products that do not have the correct identification are not reimbursed. India could establish an even better system in the coming decade, assuming that ubiquitous Internet connectivity, cloud-based services, and the Internet of Things become available. This would reduce preventable deaths and curb the sale of substandard and counterfeit drugs in India.

POTENTIAL IMPACT

The potential impact of improved health care is tremendous for a country like India, with massive economic and social implications. If the number of years of life lost by Indians to ill health were reduced to the average rate of developing economies, for example, that would be worth $90 billion to $170 billion annually, just in terms of increased worker incomes.[60] Of course, it is difficult to attribute a certain proportion of this potential improvement to technology alone—an integrated set of improvements across nutrition, clean drinking water, sanitation, and public system governance is required.

We focus here on the potential impact from the technology-based health-care applications we have identified and sized. Together, they can provide value of $25 billion to $65 billion per year in India in 2025 (Exhibit 32). We assume that remote care and technology-enablement of health-care workers reach 60 to 80 percent of all primary health centres in 2025, leading to a 50 percent reduction in average number of working days lost to illness by patients who use these services, which would be worth $19 billion to $47 billion per year in 2025. More importantly, these applications could bring health security to some 400 million people.

We estimate that 20 to 40 percent of patients suffering from life-threatening and chronic diseases such as cancer, cardiovascular disease, and Type 2 diabetes could have access to personalised genomics-based medicine that could increase their average life expectancy by six months to one year, leading to $5 billion to $10 billion in additional productivity across the economy.

Widespread adoption of electronic medical records can create an economic impact of $3 billion per year by saving 3 to 4 percent of physician and nursing time and reducing duplicated tests by 10 to 15 percent. And we estimate that improved tracking methods could cut counterfeit drugs by 20 to 50 percent, reducing losses by $1 billion to $4 billion per year in 2025.

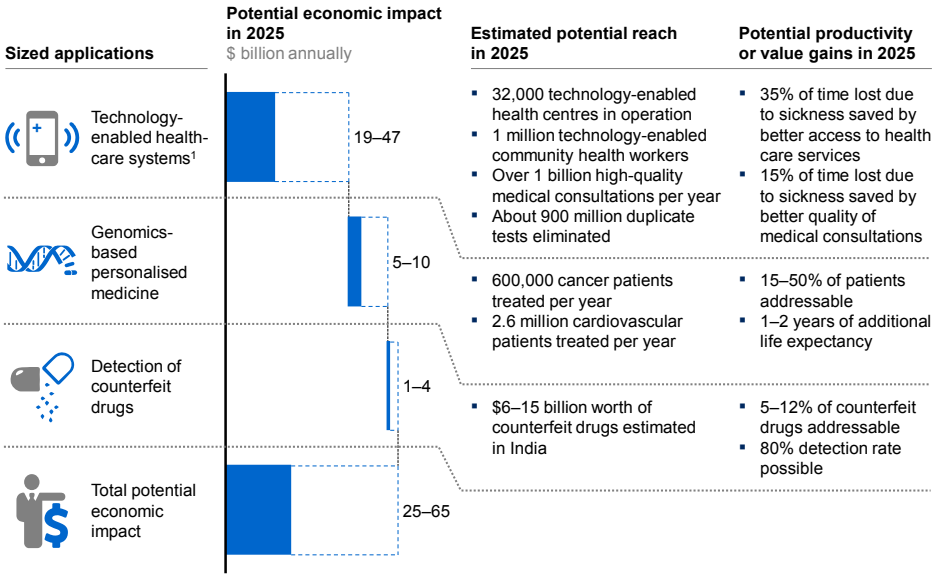
In addition to the direct economic benefits of the new technologies, indirect benefits such as creating knowledge-based jobs for workers with modest levels of formal education are possible. We estimate that three million to four million health-care workers can be trained and equipped to deliver primary health care when they are connected via the mobile Internet with expert physicians through video,

60 Based on reducing the average number of disability-adjusted life years (DALYs) per person in India from the current 0.42 to 0.34 (the average for developing economies). One DALY can be thought of as one lost year of “healthy” life. The sum of DALYs across the population can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.

voice, or chat. Many of them could be community-based health workers without conventional medical education.

Exhibit 32

Selected technology-based applications in Indian health care can have economic impact of $25 billion to $65 billion per year in 2025


Sized applications
Potential economic impact in 2025
$ billion annually
Estimated potential reach in 2025
Potential productivity or value gains in 2025
Technology-enabled health-care systems[1]
19–47
32,000 technology-enabled health centres in operation
1 million technology-enabled community health workers
Over 1 billion high-quality medical consultations per year
About 900 million duplicate tests eliminated
35% of time lost due to sickness saved by better access to health care services
15% of time lost due to sickness saved by better quality of medical consultations
Genomics-based personalised medicine
5–10
600,000 cancer patients treated per year
2.6 million cardiovascular patients treated per year
15–50% of patients addressable
1–2 years of additional life expectancy
Detection of counterfeit drugs
1–4
$6–15 billion worth of counterfeit drugs estimated in India
5–12% of counterfeit drugs addressable
80% detection rate possible
Total potential economic impact
25–65

1 Includes the integrated impact of remote health care, technology-enabled health-care workers, electronic medical records, and low-cost medical devices.

NOTE: Estimates of potential economic impact are for some applications only and are not comprehensive estimates of total potential impact. Estimates include consumer surplus and cannot be related to potential company revenue, market size, or GDP impact. We do not size possible surplus shifts among companies and industries, or between companies and consumers. These estimates are not risk- or probability-adjusted. Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

Adoption of new delivery models and processes in health care is held back not by a lack of technology, but by human and institutional factors—resistance to change in how care is delivered, the ways in which medical professionals and institutions operate, and how different stakeholders in public health work together. As a result, many pilot programmes remain localised and do not scale up. In addition, health-care professionals have limited understanding of technology; even now, the public health system struggles to use available technologies. Change is also frustrated by the number of stakeholders in health care. Separate health authorities operate at the national and state levels, and no simple system coordinates the efforts of government, NGOs, health-care experts, and technology companies.

To overcome these obstacles and take advantage of empowering technologies to improve Indian health care, action will be needed by government and policy makers as well as by the private sector. Governments could start by making use of technology to improve the capabilities of existing public health centres a top priority. India has more than 175,000 public health centres (primary health centres, subcentres, community health centres, and district hospitals), and the number will grow by 2025. Today, many public health facilities lack computers and diagnostic equipment—or even reliable electricity. At a minimum, health centres should be equipped with Internet access, tablets or smartphones for health workers, and solar or battery-based electricity supply. These simple setups

can enable the use of clinical decision-support systems, attendance monitoring, health worker management systems, video-based remote consultation, and low-cost diagnostic devices. Similarly, existing high-priority national health programmes to reduce infant and maternal mortality and to curb HIV and polio, for example, can benefit enormously from technologies such as disease mapping and remote diagnostics.

State governments can support innovative new delivery models in health care at the local level. Technology-enabled community-based, low-cost health-care outreach networks, such as SughaVazhvu and the Health Management and Research Institute, can be expanded. Variants of these models can be created for each state and local region tailored to local needs and resources (talent, private-sector institutions, and local non-governmental organisations). The state can help by using public funding to expand such networks and setting performance standards to evaluate success and boost acceptance. Finally, the government can support targeted research into low-cost diagnostic technologies to reduce the overall cost of treatment. For example, government funding already has helped Mumbai-based startup Biosense develop a non-invasive anaemia scanner.

5. Agriculture and food

India's agriculture sector has made great strides in the period following its Green Revolution, but immense potential remains for improvement in productivity and value addition. The sector is at a very early stage of technology adoption—many farmers still have no mechanised tools. Concerted policy efforts to deploy technology in the agriculture and food distribution sector can transform virtually every part of the value chain, benefiting both producers and consumers. We estimate that technology-based applications and services can help unlock $45 billion to $80 billion of economic impact, help 90 million farmers earn higher incomes, and provide better nutrition for 200 million to 250 million people in 2025. Adoption of digital technologies, GIS, advanced transportation, and genomic technologies can help India raise farm productivity, bring more of what it grows to market, raise the level of food security across the country, and improve the livelihoods of the 60 percent of India's working poor who depend on agriculture.

CHALLENGES TO INDIAN AGRICULTURE AND FOOD DISTRIBUTION

India's Green Revolution, a yield improvement programme initially undertaken from the late 1960s to the late 1970s, made India self-sufficient in grains such as rice and wheat. In the past decade, yields of oilseed, pulses, cotton, fruits, and vegetables have grown by 3 to 5 percent per year.[61] India is currently the third-largest agricultural producer in the world after China and the United States, and it is the top producer of bananas, mangoes, papayas, milk, buffalo meat, spices, castor oil seeds, and sesame seeds. However, agricultural productivity in India is still low. In addition to facing a productivity challenge, Indian agriculture needs to diversify its output to meet the nation's nutrition needs and raise incomes of poor farmers.

Low farm yields

Despite the Green Revolution and subsequent progress, Indian yields remain 10 to 50 percent lower than Asian averages, and the difference has widened over the past three decades. The yield gap with China has grown from 1.5 tonnes per hectare to 5.1 tonnes; from one tonne per hectare to 3.2 tonnes with Vietnam; and from 1.6 to 2.8 tonnes per hectare with Malaysia. Within India, there are significant variations among regions due to differences in climate as well as in the use of productivity-improving inputs such as irrigation, mechanised equipment, and fertilisers—and tailored responses are required to increase yields. We estimate that India's average crop yield of 2.3 tonnes per hectare could rise by 72 percent to the Asian average of about 4 million tonnes per hectare. Some 60 percent of this improvement can be realised through better soil conditioning (with fertiliser and manure), water management, and better seed quality. Tailoring the use of inputs such as seeds, fertilisers, equipment, and other precision farming practices based on the specific conditions in a particular field can result in a further 22 percent of the yield improvement, we estimate. Finally, improved

61 Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

post-harvest logistics and better market access can reduce crop waste by 50 percent, improving yields by about 18 percent.[62]

Demand for diversified food

For virtually every segment of the population, higher incomes are translating into higher demand for non-cereal–based foods—pulses, milk, fruit and vegetables, eggs, fish, and meat. Today, a diversified diet is out of reach for many: only 55 percent of women consume milk or dairy on a weekly basis, only 40 percent eat fruit at least once a week, and only 32 percent eat eggs at least once a week.[63] Food inflation has been a persistent challenge. To meet the population's evolving food needs, the output of non-cereal–based foods and food processing sectors need to improve substantially. Growth in sector output would need to be 5.2 to 5.7 percent each year over the next two decades.[64] Successful diversification would depend on access to market information and a reliable distribution infrastructure to provide safe and efficient distribution of perishables.

Distribution inefficiencies

Post-harvest distribution is plagued by inefficiencies due to a lack of proper infrastructure, an inefficient procurement and distribution system for government food allotments, and poorly functioning private markets. India has storage capacity for only about 10 percent of the fresh produce it raises, and most of that capacity is concentrated in the north.[65] An estimated 30 percent of fruit and vegetable crops is lost to theft and spoilage.[66] Of the food that is purchased for the poor under the public distribution system (PDS), an average of 36 percent is lost to leakage—in Uttar Pradesh and Bihar, the rates are 60 to 80 percent—and an estimated 65 percent of PDS allotments for people below the official poverty line does not reach the intended recipients.[67] Private markets are also inefficient, due to outdated regulations that created a government-supported network of private *mandis* (markets). In theory, prices are determined through auctions, but many markets are dominated by middlemen and farmers have little visibility into prices. Across the distribution system there is little transparency and market information, leading to large imbalances in supply and demand, including between regions. These imbalances result in artificial shortages and price distortions.

India has the potential to address these challenges by adopting a series of technologies that begin in the planting of crops and continue all the way through to retail distribution. Applied correctly, these technologies can put India on course to meet the food needs of its growing population in the next three decades and improve overall nutrition.

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62 For a detailed discussion on improving agricultural yields and farmer incomes in India, see *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014

63 *Third National Family Health Survey (NFHS-3), 2005–06*, Ministry of Health and Family Welfare, Government of India, 2007.

64 *India as an agriculture and high-value food powerhouse: A new vision for 2030*, McKinsey & Company and Confederation of Indian Industry, April 2013.

65 *The food wastage and cold storage infrastructure relationship in India: Developing realistic solutions*, Emerson Climate Technologies, 2013.

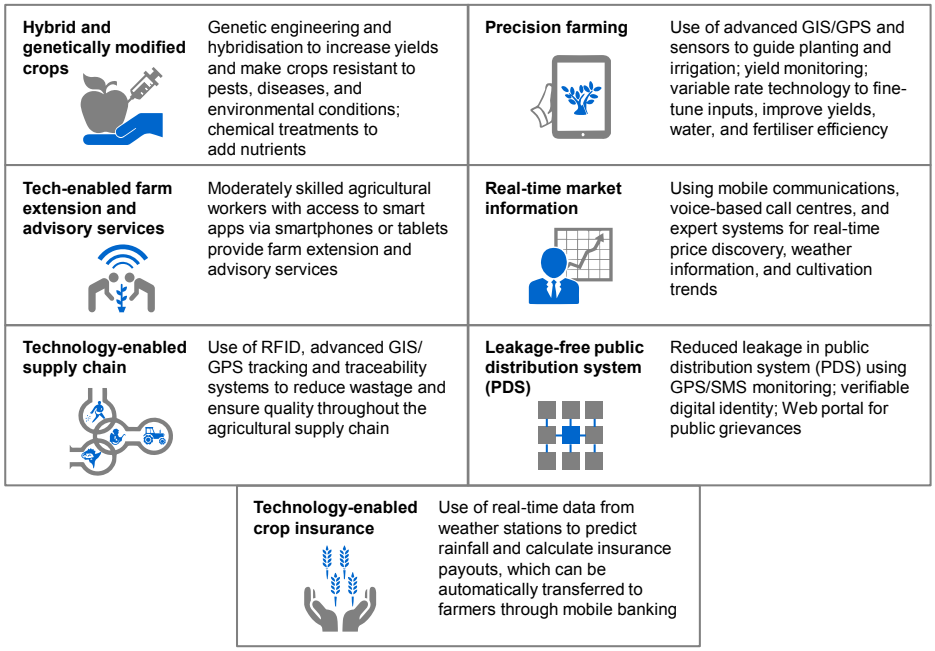
66 Minister of state for food and agriculture at CII Cold Chain Summit, reported in "India wastes 59 MT fruits, vegetables every year", *Business Standard*, December 21, 2010.

67 For details, see *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

We highlight seven technology applications that have the power to reshape India's agriculture sector (Exhibit 33).

Exhibit 33
Seven technology-based services can transform Indian agriculture


Hybrid and genetically modified crops
Genetic engineering and hybridisation to increase yields and make crops resistant to pests, diseases, and environmental conditions; chemical treatments to add nutrients
Precision farming
Use of advanced GIS/GPS and sensors to guide planting and irrigation; yield monitoring; variable rate technology to fine-tune inputs, improve yields, water, and fertiliser efficiency
Tech-enabled farm extension and advisory services
Moderately skilled agricultural workers with access to smart apps via smartphones or tablets provide farm extension and advisory services
Real-time market information
Using mobile communications, voice-based call centres, and expert systems for real-time price discovery, weather information, and cultivation trends
Technology-enabled supply chain
Use of RFID, advanced GIS/GPS tracking and traceability systems to reduce wastage and ensure quality throughout the agricultural supply chain
Leakage-free public distribution system (PDS)
Reduced leakage in public distribution system (PDS) using GPS/SMS monitoring; verifiable digital identity; Web portal for public grievances
Technology-enabled crop insurance
Use of real-time data from weather stations to predict rainfall and calculate insurance payouts, which can be automatically transferred to farmers through mobile banking

SOURCE: McKinsey Global Institute analysis

Hybrid and genetically modified crops

Hybrid seeds, which have been a focus of India's government, will play a major role in increasing agricultural productivity. Hybrid rice seeds produce yields that are 10 to 15 percent higher than public (or naturally occurring) rice seeds, and the National Food Security Mission aims for the share of Indian rice fields planted with hybrids to reach 25 percent in the next three to five years. The hybrid share of maize planting is expected to reach 90 percent by 2050, up from 60 percent today.[68] Increased use of hybrid seeds could significantly boost food production in India.

Genetically modified (GM) crops have been approved for use in 29 countries, where they are raising yield by introducing modifications such as drought resistance and the ability to repel certain insects. GM variations have been developed for soybeans, wheat, maize, cotton, canola, squash, papaya, alfalfa, and sugar beets. In 2002, India approved GM cotton, which is being grown in Maharashtra, Gujarat, Andhra Pradesh, Madhya Pradesh, Punjab, and Haryana and now accounts for more than 90 percent of all cotton planted in India. Yields increased from 300 kilograms per hectare in 2003 to 500 kilograms per hectare in 2010, according to the Cotton Advisory Board (Exhibit 34).

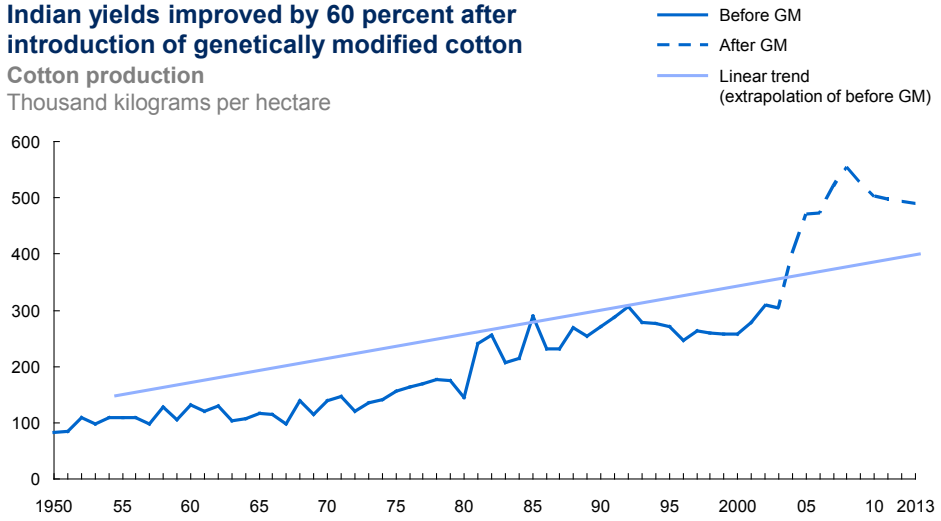
68 *Vision 2050*, Directorate of Maize Research, Indian Council of Agricultural Research, 2012.

Exhibit 34

Indian yields improved by 60 percent after introduction of genetically modified cotton

Cotton production

Thousand kilograms per hectare



SOURCE: Cotton Advisory Board; McKinsey Global Institute analysis

Advanced genomics could accelerate the proliferation of GM crops, but use of GM crops remains controversial, due to environmental and health concerns and the GM economic model, which requires farmers to purchase seeds each year. The price of GM seeds has been an issue for poor farmers in India, and Gujarat and other states have imposed price caps to protect farmers. There are also concerns about GM seeds migrating into non-GM fields and introducing mutations into other plant species and limiting biodiversity. In addition, there are concerns about the health effects of genetically modified foods. The European Union recently approved a ruling to permit individual nations to ban GM crops. In India, the Supreme Court-appointed Technical Expert Committee called for a moratorium on field trials of GM crops in 2013, but in 2014, the Genetic Engineering Appraisal Committee (which regulates the use of genetically engineered organisms) revalidated ten varieties of GM crops for "confined field trials". The crops include wheat, rice, and maize, subject to approval from state governments. Non-edible crops such as GM jute could be approved for planting, but GM foods may have to wait for more regulatory clarity.

Precision farming

Precision farming is a data-driven approach to raising farm yields by using GIS data and information about soil, weather, and ecological conditions for a specific piece of land—or in different spots within a tract—to optimise the choice of crops and the use of fertilisers, pesticides, and water, and to determine when and how to till, spray, and harvest. This involves use of GPS and advanced GIS technology and sensors to gather information in different parts of a field. It has been estimated that precision farming techniques have contributed 79 to 96 percent of the total increase in the global supply of wheat, rice, and maize since 1967; and that, without precision farming, 446 million additional hectares would have been needed for production of these crops.[69]

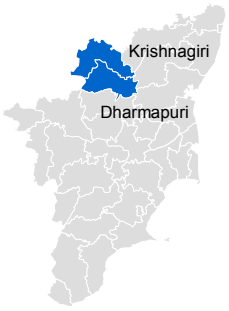
69 Kenneth G. Cassman, "Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture", *Proceedings of the National Academy of Sciences of the United States of America*, volume 96, number 11, May 1999.

Most of this benefit has been seen in the large, industrialised farms of developed economies, where the technology has been developed. The challenge in developing economies such as India is to apply precision farming to smallholder farms. Some 83 percent of Indian farms are less than two hectares. These small-scale farms account for 41 percent of all sown area in India and have been worked for generations without use of scientific assessments or data to guide farming decisions. However, precision farming techniques are beginning to be used in India. The state-sponsored Tamil Nadu Precision Farming Project, which ran from 2004 to 2007, tested the concept for India (Exhibit 35). It used GIS-based field and soil mapping, and drip irrigation and fertilising systems. Some 400 hectares were planted with 23 kinds of crops over three years, including pest- and disease-resistant varieties. Yields were 60 to 80 percent higher than in conventional farming, and 95 percent of the harvests were of first-grade marketable quality.[70] In addition, precision farming makes better use of India's limited water resources. One study showed that irrigation efficiency can meet one-third of the incremental water demand through 2030.[71]

Exhibit 35
Tamil Nadu Precision Farming Project: An integrated approach raises farmer productivity

Pilot description

- Implemented from 2004–07 in the districts of Dharmapuri and Krishnagiri
- Covered 400 hectares with 23 kinds of vegetables planted over two years



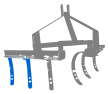
Key technologies used

Remote sensing technology

GIS used to develop physiographic, soil, and land-use maps of the districts; precise application of nutrients based on data analyses

High-tech community nursery

Uniform seedlings raised under insect-proof netting



Chisel plough

Chisel-plough technology used for better aeration to root zone and effective rainwater drainage

Drip and fertigation system

Integrated drip irrigation and fertiliser systems ensured water economy and precise application of water-soluble fertilisers to root zone and also kept an ideal moisture regime

Other important interventions

Co-location of scientists with farmers
- Field scientists stayed in villages and provided technical support throughout growing season

Connecting efforts to market needs
- Farmers taken to markets in Cochin, Chennai, Bangalore, Safal, and Coimbatore to see the importance of minimal grading and sorting and timely delivery
- Buyers from the market were taken to the project site to showcase the healthy, high-tech production system

Impact

60–80%
Higher yield in all crops

30%
Premium price in the market

95%
First-grade marketable produce

30–40%
Water economy

25%
Higher weight by volume

5–6 days
More shelf life

- Extended harvest ensuring sales during the period of peak price
- Empowerment of farmers technically, economically, and socially
- Reduction in pesticide usage
- Availability of insurance coverage at attractive premiums

SOURCE: Tamil Nadu Precision Farming Project, Operational Guidelines; McKinsey Global Institute analysis

70 Tamil Nadu Precision Farming Project.

71 *Annual report: 31 December 2013*, Water Resources Group, April 2014.

Tata Chemicals' Tata Kisan Sansar network (previously known as Tata Kisan Kendra) is acting as a resource for Indian farmers who want to learn precision farming techniques. From 800 centres, the company provides training as well as access to GIS data to analyse conditions in different farm areas. The initiative has created digitised maps of nearly 12,000 villages, and Tata encourages adoption of modern practices by offering prizes to farmers who produce the best yields.

E-enabled farm extension and advisory services

India's small farmers could improve their yields and raise the value of their crops if they had better access to the know-how that farm extension workers are hired to provide. However, the Department of Agriculture has only about 750 extension workers per million farmers. Vietnam and China have 2,500 to 3,500 farm extension workers per million farmers. India's public extension system also faces challenges such as poor coordination between field workers and research teams, and vacant posts in remote areas. There are few opportunities for farmers to provide feedback, and budgets are consumed mainly by salaries, leaving little money for field travel. There has long been a shortage of government resources to train and support farm extension workers.[72]

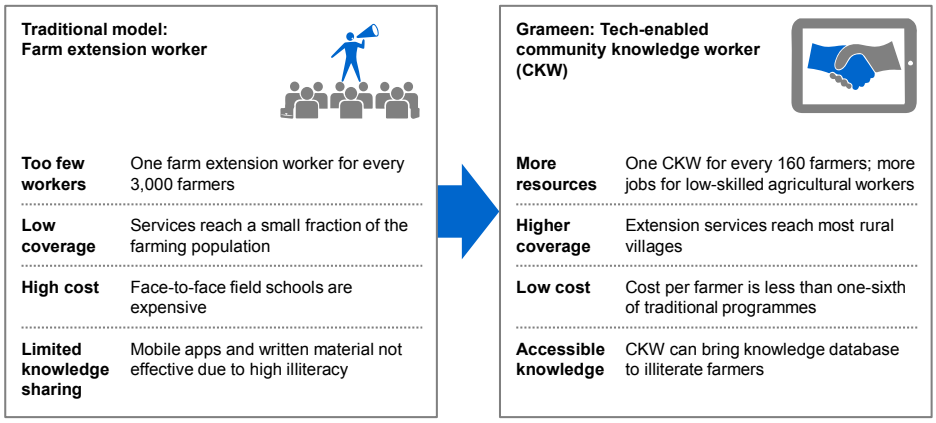
Yet the power of well-managed and coordinated farm extension services has been seen in India. In Gujarat, for instance, where the agriculture sector has grown by an unprecedented 8.2 percent annually since the early 2000s, a key part of the agricultural transformation was *krishi raths*—a fleet of vans bearing extension workers from village to village to share information on agricultural best practices and provide soil testing and other services. Private extension services (such as those offered by Mahindra ShubhLabh Services) are proving to be effective models for medium-sized and large farms that can afford the service fees.

To bring farm services to more Indian farmers, and particularly to poor farmers in remote areas who need the most help, India can invest in technology that can extend the reach of existing workers and make it possible for relatively unskilled workers to deliver farm extension services. This would be similar to the remote health-care model, in which the worker in the field uses a tablet or smartphone to pull down expert knowledge and applications from the cloud. With the right apps, an extension worker with a few weeks of training could be visiting farmers in their fields and villages to share the latest best practices, test soil and water conditions, and counsel them on when to plant or harvest.

The Grameen Foundation in Uganda uses a community knowledge worker network that could be a model for how India can rethink the way it delivers farm extension services. Community knowledge workers—moderately skilled farmers who are well-regarded in their communities and chosen by their peers—are sent into the field with smartphones programmed with apps that provide information on weather and commodity prices, as well as expert advice on crop management and pest and disease control. The workers disseminate this knowledge to farmers and train them to use the smartphone applications themselves. The network in Uganda now has more than 1,100 peer advisers serving 176,000 farmers (Exhibit 36).

72 Claire J. Glendenning, Suresh Babu, and Kwadwo Asenso-Okyere, *Review of agricultural extension in India: Are farmers' information needs being met?* International Food Policy Research Institute discussion paper 01048, December 2010.

Exhibit 36
In Uganda, technology has made farmers community knowledge workers


Traditional model:
Farm extension worker
Too few workers
One farm extension worker for every 3,000 farmers
Low coverage
Services reach a small fraction of the farming population
High cost
Face-to-face field schools are expensive
Limited knowledge sharing
Mobile apps and written material not effective due to high illiteracy
Grameen: Tech-enabled community knowledge worker (CKW)
More resources
One CKW for every 160 farmers; more jobs for low-skilled agricultural workers
Higher coverage
Extension services reach most rural villages
Low cost
Cost per farmer is less than one-sixth of traditional programmes
Accessible knowledge
CKW can bring knowledge database to illiterate farmers

SOURCE: Grameen Foundation; McKinsey Global Institute analysis

Real-time market information

Once crops are ready for sale, Indian farmers encounter a complex and opaque market system. With a lack of information about prices and demand (historical or current), farmers do not know what they should expect at harvest time. The lack of information also affects supply and demand; farmers who are several steps down the supply chain from actual food buyers have no insights into patterns of demand and cannot make informed decisions about what to plant. They also operate in a vacuum of information regarding weather conditions and pest outbreaks, which can affect market prices.

Mobile phones provide an excellent means to bring farmers real-time information about prices, weather demand, and other market factors—and to let farmers provide their own data about supply trends, new varieties in the market, and best practices in storage and sale. With information gathered and shared at every step of production, harvesting, transportation, and sale, all market participants can have access to timely supply, demand, and pricing data. Such information can inform decisions on when to plant, harvest, and ship.

Through the "e-choupal" system set up by ITC, a large Indian conglomerate, 6,500 virtual *choupals* (meeting places) have linked four million Indian farmers across ten states into a shared information system. The e-choupal is a kiosk equipped with Internet access and managed by a trained local farmer. It provides a marketing channel for produce, as well as information on weather, agricultural practices, input and output quality, and testing facilities. According to a study done in 2009, farmers who have used the e-choupals have sold their crops for 2.5 percent more than the prices realised by farmers at local *mandis*.[73]

The news and data company Reuters has created a mobile phone service called Reuters Market Light that provides farmers with personalised information—such as tailored weather reports—through SMS texts in their local languages (Exhibit 37). About 1.3 million subscribers from more than 50,000 villages across 13 states have used the service, and the total reach (farmers sharing Market Light

73 Rajiv Mehta, *India's Agricultural Marketing Information System Network*, United Nations Food and Agricultural Organization, 2009.

data) is estimated to be about five million, Reuters says. The service covers more than 300 crop varieties and disseminates price information from more than 1,300 markets. Users have been found to achieve a 5 to 25 percent increase in incomes after using the service, according to mobile carrier Vodafone.[74]

Exhibit 37
Reuters Market Light provides real-time agricultural market information

Customised data service for farmers

Real-time information delivered via mobile phones:
- Crop advisory
- Tailored weather forecasts
- Local market price information
- Local and international commodity data
- Other relevant information

Impact

Reach
- Launched in Maharashtra in 2007; now available in 13 states, covering more than 300 crop varieties
- 1.3 million subscribers in more than 50,000 villages
- Available in eight languages and on all mobile networks and handsets

Benefits
- Subscriber interviews report 5–25% increase in income
- 90% of surveyed farmers say they benefited from the service, and more than 80% say they would pay for it
- An estimated 12% reduction in price dispersion across markets

SOURCE: Reuters Market Light; *The impact of mobile phones*, Indian Council for Research and International Economic Relations policy paper series number 9, January 2009; Chris Parker, Kamalini Ramdas, and Nicos Savva, *Is IT Enough? Evidence from a natural experiment in India's agriculture markets*, London Business School, 2013; McKinsey Global Institute analysis

Technology-enabled supply chain

One of the biggest challenges in the Indian agriculture and food sector is post-harvest crop losses. Some 30 percent of fruits and vegetables (40 million tonnes per year) are lost to spoilage on the way through the distribution system. This adds up to losses of about $4 billion per year in the Indian food distribution system and contributes to food scarcity. Building warehouses, cold-storage facilities, roads, and rail links in remote areas could cut losses in Indian food distribution to just 4 to 7 percent. The use of information technology to track food across the distribution system can improve demand and supply matching across markets and locations and can also prevent waste, while helping farmers capture more value from the sale of their output. Using Internet of Things tagging and tracking technologies, Indian farmers and food distributors could monitor the progress of crops from farm to market and cut down on the amount of food spoiled in transit because of avoidable delays. In Colombia, coffee growers are using RFID tags on bags of specialty beans to certify that they are not ordinary beans and are worth prices that are as much as 200 percent above typical prices for Colombian coffee.

Leakage-free public distribution system

Nearly one-third of India's rice and wheat is procured by the government at minimum support prices, and most of this food finds its way into the public distribution system. Grain is transported and stored by the Food Corporation of India and then distributed by the states through a network of more than 400,000 fair price shops. Leakage in the PDS is estimated to be 36 percent at an all-India

74 *India: The impact of mobile phones*, Indian Council for Research on International Economic Relations policy paper series number 9, January 2009.

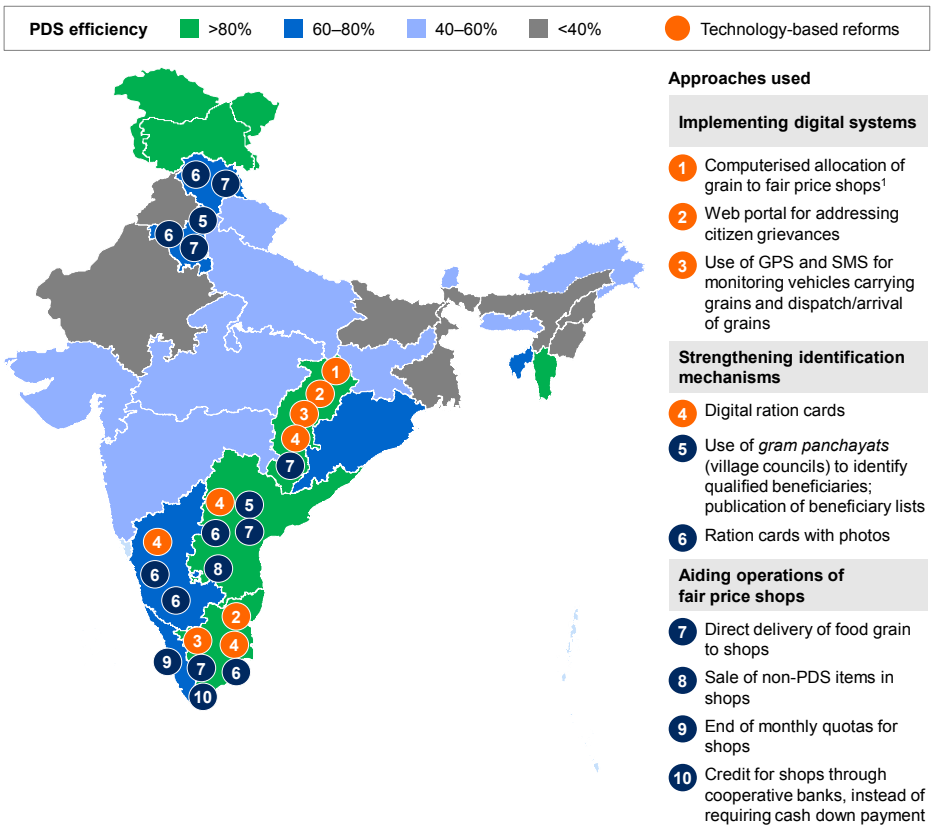
level and significantly higher in certain states and among the poorer segments of the population.

A series of tech-enabled measures can be used to reduce PDS leakage, by tracking grain in the supply chain and verifying that people receiving PDS food are truly eligible. Simple fixes include basic computerisation of beneficiary lists (many are still on paper), issuance of smart cards to beneficiaries to record transactions, computerisation of the accounting and monitoring systems in the Food Corporation of India (which manages PDS operations) and in the fair price shops; the use of computerised fleet management systems and RFID-tagging to monitor and guide the movement of trucks carrying food grains; and automated text-message alerts to let villagers know when grain shipments are scheduled to arrive. Many of these interventions have been successfully implemented in different parts of India (Exhibit 38). If they were adopted nationally, we estimate that PDS losses could be reduced to 8 to 10 percent, the level of the best-performing states.

Exhibit 38

Leakage in PDS payments has been cut by using computerised allocation, identity systems, tracking, and improved fair price shop operations

Interventions by states where more than 60% of PDS subsidy reaches consumers


PDS efficiency
>80%
60–80%
40–60%
<40%
Technology-based reforms
Approaches used
Implementing digital systems
1 Computerised allocation of grain to fair price shops[1]
2 Web portal for addressing citizen grievances
3 Use of GPS and SMS for monitoring vehicles carrying grains and dispatch/arrival of grains
Strengthening identification mechanisms
4 Digital ration cards
5 Use of gram panchayats (village councils) to identify qualified beneficiaries; publication of beneficiary lists
6 Ration cards with photos
Aiding operations of fair price shops
7 Direct delivery of food grain to shops
8 Sale of non-PDS items in shops
9 End of monthly quotas for shops
10 Credit for shops through cooperative banks, instead of requiring cash down payment

1 Government- or privately run shops that are entrusted with distributing food grain to consumers.

SOURCE: Raghav Puri, "Reforming the public distribution system: Lessons from Chhattisgarh", *Economic and Political Weekly*, volume 47, number 5, 2012; Surajit Deb, "Public distribution of rice in Andhra Pradesh: Efficiency and reform options", *Economic and Political Weekly*, volume 44, number 51, December 2009; McKinsey Global Institute analysis

Technology-enabled crop insurance

Farmers risk severe income losses due to weather calamities such as drought, flood, and extreme temperature. Crop insurance programmes exist, but they are often plagued by fraud, corruption, and adverse selection problems (when only high-risk customers purchase coverage).[75] Conventional crop insurance also relies on direct measurement of losses, which requires on-site inspection—a costly approach, especially with a large number of small-scale farmers.

A newer approach is technology-enabled "weather-index" crop insurance, which replaces direct measurement with reading of key parameters such as rainfall or temperature at a specific weather station during an agreed time period. The policy is drafted to specify parameters that correlate as closely as possible with the loss that the farmer might suffer. All policyholders in a particular area receive payouts based on the same contract and measurement, removing the need for in-field assessment.

In the Kilimo Salama (safe farming) weather-index programme launched by global agribusiness company Syngenta in Kenya in 2009, solar-powered weather stations are used to collect data and transmit measurements to a cloud-based server. At the end of each growing season, the data are automatically compared with an index based on historical weather data. If the season's rainfall is 15 percent above or below the average, the insurance payout owed to client farmers is calculated without the need for a claims process and is sent via a mobile banking payment system. Because Kilimo Salama has been able to keep transaction and operational costs to a minimum, it can market micro-insurance schemes in which farmers can insure small assets, such as coverage on $2 of seeds for just 10 cents. By the end of 2013, Kilimo Salama had insured 187,000 farmers in three countries.[76]

POTENTIAL IMPACT

We estimate that the empowering technology applications could have potential economic impact of $45 billion to $80 billion annually in 2025 and would benefit up to 90 million farmers (Exhibit 39).

Technology-enabled food distribution (in both the public and private systems) would make the largest contribution, perhaps $27 billion to $32 billion of economic impact per year by 2025. This is based on the assumption that technology-based measures are adopted across the public distribution system, raising overall efficiency and reducing leakage across India to the levels in India's best-performing states that have already implemented PDS reforms. In the private food distribution system, we assume that the current level of food wastage and loss could be reduced by half through better monitoring, introduction of IT-enabled warehouses, and improved transportation (refrigerated trucks, for example, or trucks with GPS monitors).

75 Jim Roth and Michael J. McCord, *Agricultural microinsurance: Global practices and prospects*, The MicroInsurance Centre, LLC, 2008.

76 Syngenta Foundation.

We estimate that if precision farming is expanded to 25 to 30 percent of sown area, yields could increase by 15 to 50 percent, representing a potential economic value of $8 billion to $30 billion per year. Additional (unquantified) benefits would include lower water consumption and more optimised use of fertiliser and pesticide.

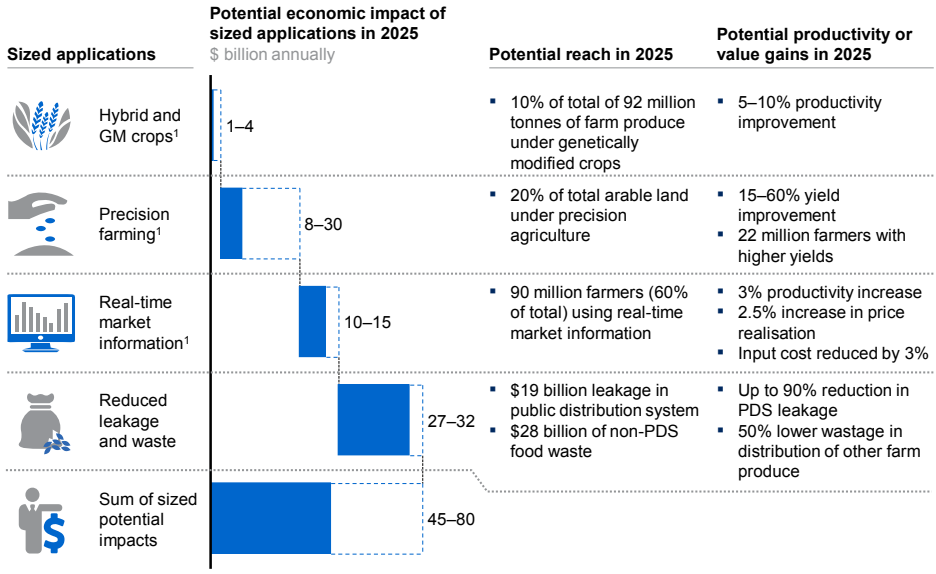
If real-time market information can reach 90 million farmers, we estimate that the resulting increases in productivity, higher price realisation, and reduction in input costs could be worth $10 billion to $15 billion per year in 2025.

In view of significant concerns around GM technology, we assume a modest gain in seed technology and estimate that 20 percent of arable land in India would be planted in hybrid and genetically modified crops in 2025, producing potential economic impact of $1 billion to $4 billion a year.

In addition to these economic gains, improvements in the productivity of Indian agriculture could have enormous societal and humanitarian benefits. We estimate that improvements in the PDS to reduce leakage could benefit 200 million to 250 million recipients. Also, the tech-enabled farm extension plan could create jobs for as many as one million community farm workers by 2025.

Exhibit 39

Selected technology-based applications in Indian agriculture can have economic impact of $45 billion to $80 billion per year in 2025


Sized applications
Potential economic impact of sized applications in 2025
$ billion annually
Potential reach in 2025
Potential productivity or value gains in 2025
Hybrid and GM crops[1]
1–4
▪ 10% of total of 92 million tonnes of farm produce under genetically modified crops
▪ 5–10% productivity improvement
Precision farming[1]
8–30
▪ 20% of total arable land under precision agriculture
▪ 15–60% yield improvement
▪ 22 million farmers with higher yields
Real-time market information[1]
10–15
▪ 90 million farmers (60% of total) using real-time market information
▪ 3% productivity increase
▪ 2.5% increase in price realisation
▪ Input cost reduced by 3%
Reduced leakage and waste
27–32
▪ $19 billion leakage in public distribution system
▪ $28 billion of non-PDS food waste
▪ Up to 90% reduction in PDS leakage
▪ 50% lower wastage in distribution of other farm produce
Sum of sized potential impacts
45–80

1 Integrated with digital farm extension and advisory services.
NOTE: Estimates of potential economic impact are for some applications only and are not comprehensive estimates of total potential impact. Estimates include consumer surplus and cannot be related to potential company revenue, market size, or GDP impact. We do not size possible surplus shifts among companies and industries, or between companies and consumers. These estimates are not risk- or probability-adjusted. Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

The challenges of technology adoption in the agricultural sector cannot be minimised. Land holdings are fragmented, and smallholders have limited resources to invest in technology. Farmer education levels and awareness of advanced agricultural techniques are extremely low. Investments in farm extension services and agricultural R&D have been constrained. The variation in climate, crops, and farming approaches across India means that solutions need to be customised and managed in a decentralised way. There is widespread disagreement among farmers, private seed companies, environmentalists, scientists, and state governments on the use of GM crops. Not all state governments have embraced the use of technology in reforming the public distribution system, despite demonstrated success of these strategies in some parts of India.

To encourage precision farming and technology-enabled farm extension and advisory services, the state agricultural universities can be revitalised through private participation. With private-sector help, universities could also recruit, train, and supervise a new group of tech-enabled farm extension workers. These universities also can develop the expert systems and other apps that extension workers would need and help create GIS databases for soil and water resources. To clarify India's position on GM crops, a clear regulatory framework could be developed, which would represent all stakeholders and govern production, pricing, and sale of seeds.

To promote faster adoption of technology for real-time market information, states could be required to disseminate prices via text messaging. A special incentive fund for technology investment can be created to encourage wholesale agricultural markets to digitise their operations and share market data. Similarly, a timetable can be laid out for states to implement best practices in PDS management. Procedures for direct purchase of agricultural produce by private retail players can be further simplified by issuing single-window licences for multiple states and multiple commodities and by relaxing agricultural stocking and movement limits. This would encourage more organised retail players to build infrastructure and technology for agricultural markets.

6. Energy

India is badly in need of the help that empowering technologies can provide for its energy sector. Unconventional oil and gas could potentially be a game changer for India, but it needs widespread adoption and in some cases development of technologies ranging from high-resolution imaging to geomechanical studies, lean drilling, and fracturing (fracking). Renewables, such as solar and wind, could play a much larger role in electricity generation, but full development of these resources in India may require breakthroughs such as offshore wind and utility scale solar. Smart metering can help India cut down the massive distribution losses that electric companies suffer in the short term, and new energy storage technologies can help improve the reliability of power supply. Put together, these empowering technologies could have an economic impact of $50 billion to $95 billion per year in 2025 and bring the benefits of a stable and adequate electricity supply to 80 million to 110 million Indian households by that time.

INDIA'S ENERGY CHALLENGE

India, now the world's third-largest economy, is the fourth-largest energy consumer, after the United States, China, and Russia. As the economy grows and the population rises, India's energy demand is expected to rise from an estimated 691 million tonnes of oil equivalent in 2010 to 1,240 million tonnes of oil equivalent in 2025.[77] However, India has developed a very limited supply of domestic resources, has an underdeveloped and unreliable electricity supply, and faces social challenges related to energy; it has been unable to bring electricity to a large share of the population and has a relatively large carbon footprint.

Limited energy resources and high reliance on imports

The subcontinent is home to 17 percent of the world's population but possesses only 0.6 percent of proven global oil reserves, 0.4 percent of gas reserves, and 10 percent of coal reserves.[78] Population density and water shortages complicate efforts to develop onshore wind, photovoltaic (PV) solar, and biofuel crops, or to find the water needed for fracking. India today is far from energy independence; it is the world's third-largest energy importer, with 30 percent of its primary energy requirements dependent on imports. India purchases $180 billion a year in oil, liquefied natural gas, and other fuels, which account for 40 percent of all imports and 95 percent of the trade deficit.[79] Under current trends, by 2030 imports could rise to 53 percent of primary energy requirements, potentially making India one of the most energy-dependent countries in the world.[80]

77 *India: Towards energy independence 2030*, McKinsey & Company, January 2014.

78 India energy security scenarios 2047, Planning Commission of India, 2013.

79 *Report of the Working Group on Petroleum and Natural Gas for the XI Plan (2007–2012)*, Ministry of Petroleum and Natural Gas, Government of India, November 2006.

80 *India: Towards energy independence 2030*, McKinsey & Company, January 2014.

Significant issues in electricity generation and distribution

For the fiscal year ended in April 2013, production of electricity fell to 86,906 gigawatt-hours, or 8.7 percent short of demand.[81] Plant load factors—the percent of electricity produced compared with maximum capacities at generating plants—fell by more than 5 percent from 2008 to 2012, mainly due to lack of access to fuel.[82] In downstream distribution operations, India experiences high losses. Aggregate technical and commercial losses (network performance issues such as circuit overloading and theft of service) were 24 to 25 percent in 2013. This compares with 5 percent in the United States and China, 8 percent in Malaysia, 10 percent in Indonesia, and 17 percent in Brazil.[83] The resulting shortages, brownouts, and outages are disruptive to the economy and are a cause of concern for businesses. Indian SMEs and consumers face power shortages and rely on diesel generators, whose cost per kilowatt-hour can be twice the rate of that supplied by power distribution companies. Yet distribution companies have poor tariff recovery rates due to unbilled power consumption, and they have operating losses.

Social challenges result from poor energy inclusion and environmental impact. Energy inclusion is a major challenge: more than 300 million people lack access to electricity, mostly in rural areas. Even for those who have a connection, service is often intermittent. In the state of Bihar, for example, less than 20 percent of the rural population has access to electricity. Even where villages have been electrified, it is common for power to be available only two to four hours per day. India also has a large carbon footprint. Coal is used to generate 65 percent of power, and India emits more than 1,700 million metric tons of carbon per year, making it the fourth-largest contributor to global carbon emissions.[84]

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

We highlight six technologies that have the power to reshape India's energy sector and broader economy in the coming decade (Exhibit 40).

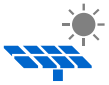
81 *Load generation balance report 2014–15*, Central Electricity Authority, Ministry of Power, Government of India, May 2014.

82 Ibid.

83 Electric power transmission and distribution losses database, World Bank.

84 Energy Information Administration's international energy statistics database.

Exhibit 40
Six technology-based services can transform India's energy sector

Unconventional oil and gas	Technologies such as non-water fracking, horizontal drilling, and fracture modelling enable recovery of previously inaccessible reserves including shale gas, coal-bed methane, and tight oil	**PV solar** 	On-grid and off-grid photovoltaic solar can reduce use of carbon-based fuels, limit emissions, and bring power to remote areas
Offshore wind, solar, and seaweed	Offshore wind, solar, and seaweed biofuels, which do not require land and fresh water, may become sources of clean energy in India	**Smart metering**	Smart meters enable demand management schemes, peak pricing, and theft detection to reduce losses
Advanced energy storage	Low-cost and efficient energy storage devices (batteries) can bring power to remote areas, enable use of renewables, and make the grid more reliable	**Energy efficiency**	Energy-saving measures such as use of CFL lighting and energy-efficient irrigation pumps; raising efficiency of power plants and trucks

SOURCE: McKinsey Global Institute analysis

Unconventional oil and gas

Production from unconventional sources (shale gas, tight gas, and coal-bed methane) has the potential to significantly increase India's domestic supply of hydrocarbon fuels. US production of shale oil has grown 24-fold in the past seven years, and shale gas production has grown six-fold.[85] This has reduced gas prices and helped the United States move from a large importer of hydrocarbons to potentially becoming a net exporter.

At this point it is not known if unconventional oil and gas could have a similar effect on India's fuel supply. However, even the most sceptical views of India's unconventional oil and gas potential acknowledge that these new sources could add significantly to India's reserves. New exploration technologies such as high-resolution imaging, geomechanical studies, and fracture monitoring could be adopted. And even though efforts to locate reserves have accelerated since the government's shale-gas policy was adopted in 2013, allowing exploration by private companies, more work needs to be done to determine India's oil and gas future. Based on estimates from the Energy Information Administration, India has 63 trillion cubic feet of shale gas reserves and 70 trillion cubic feet of coal-bed methane (Exhibit 41).

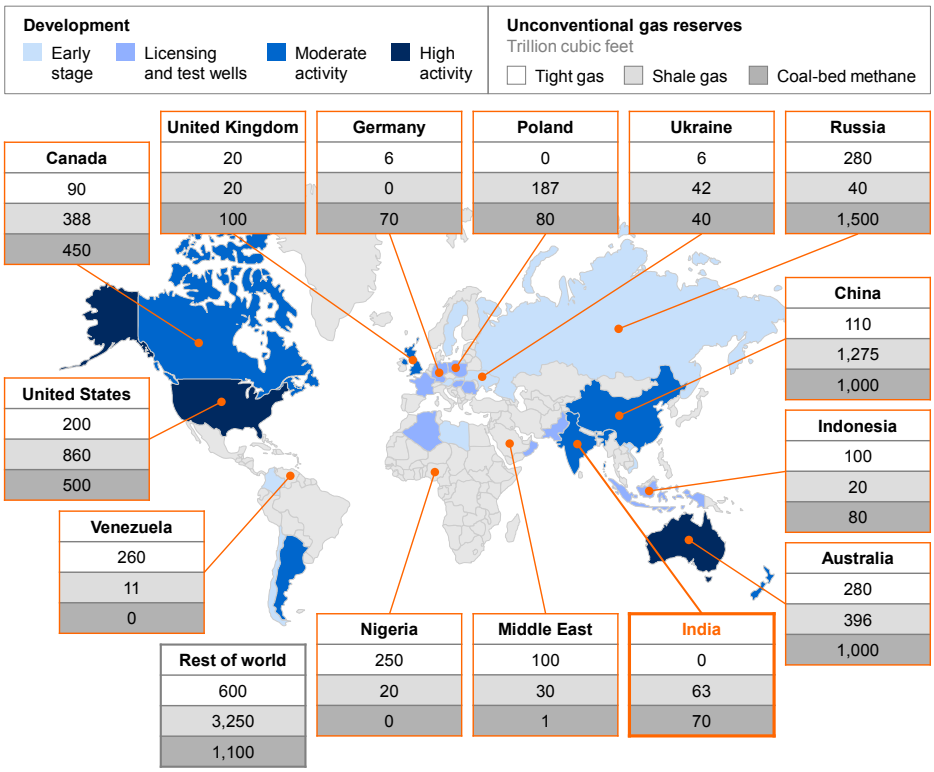
Developing reserves also requires new technologies. India awaits developments in non-water fracking methods and efficient water treatment when hydraulic fracking is used. Waterless fracking is important in India because of its tight water supply. Conventional fracking requires two million to nearly seven million gallons of water per well. As existing supplies are needed for food production and other uses, use of water for fracking would be difficult. A parallel effort in cost-efficient water treatment technologies is needed in case hydraulic fracturing has to be used eventually.

85 US Energy Information Administration.

Exhibit 41

India has undeveloped shale gas and coal-bed methane reserves

Unconventional gas reserves, 2011



SOURCE: International Energy Agency, *World Energy Outlook 2011*, November 2011; Advanced Resources International; US Geological Survey; Indian Health Service; Fox-Davis Capital; Wood MacKenzie; McKinsey Global Institute analysis

PV solar

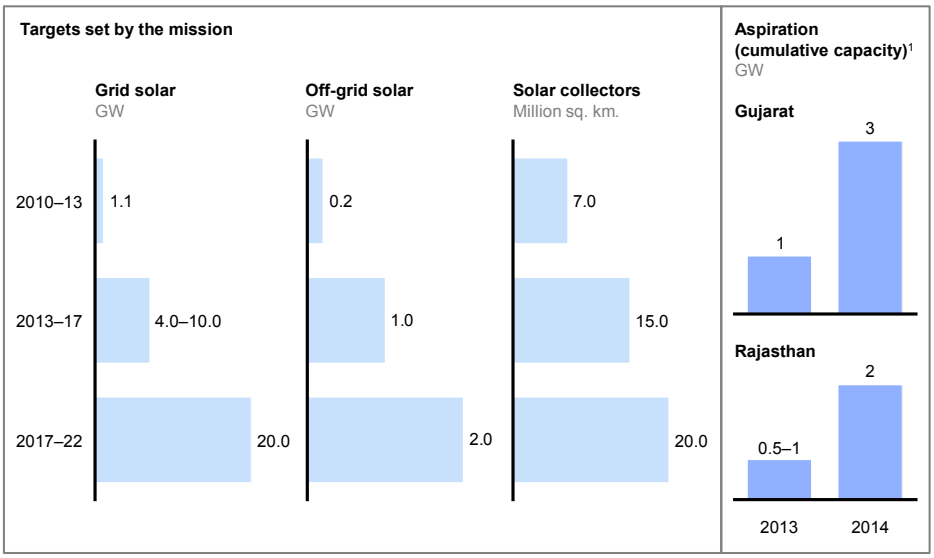
India has made a substantial commitment to expanding the use of PV solar technology to generate electricity through the National Solar Mission (Exhibit 42). Its stated goal is to add 20 gigawatts of solar capacity, or about 15 times the current level, by 2022.[86] In 2014, China's National Development and Reform Commission announced plans to more than triple installed capacity for solar to 70 gigawatts by 2017. China's government offers subsidies including funding 50 percent of the capital cost of grid-connected solar projects (and up to 70 percent in rural areas).

India's government predicts that by 2022 rooftop solar will rise to 2,000 megawatts of capacity from about 200 megawatts today, or about enough to power 100,000 households.[87] Additionally, we estimate that off-grid solutions (mostly solar, but potentially also including biomass, small-scale hydro, and wind) could bring power to 75,000 to 150,000 rural villages (upwards of 200 million people) by 2025. While this may be moderate in terms of capacity added (4 to 6 gigawatts installed capacity), it could be a critical step towards energy inclusion.

86 *Towards building Solar India*, Jawaharlal Nehru National Solar Mission, Ministry of New and Renewable Energy, Government of India, 2010.

87 Ibid.

Exhibit 42
India has an ambitious National Solar Mission



1 In addition to National Solar Mission targets; 15% of aspirations due to be complete by 2014.
NOTE: Not to scale.
SOURCE: National Solar Mission; Ministry of New and Renewable Energy; state renewable energy departments; India solar compass document; McKinsey Global Institute analysis

Offshore wind, solar, and seaweed

These technologies are still in an early stage of development but could help address India's energy challenges in the long term. While we do not size them, we highlight them here because they could address certain constraints such as limited availability of land for onshore wind and solar projects. Offshore wind could be particularly promising. Turbines located off the coast have higher utilisation factors—35 to 45 percent of capacity, compared with 20 to 25 percent onshore. Furthermore, offshore winds tend to be stronger and more consistent, and the development of offshore wind farms may involve less community resistance than onshore projects. The trade-off is the higher cost to build: $2.5 million per megawatt currently for offshore vs. $1 million for onshore. Offshore is also more complex to operate and maintain.

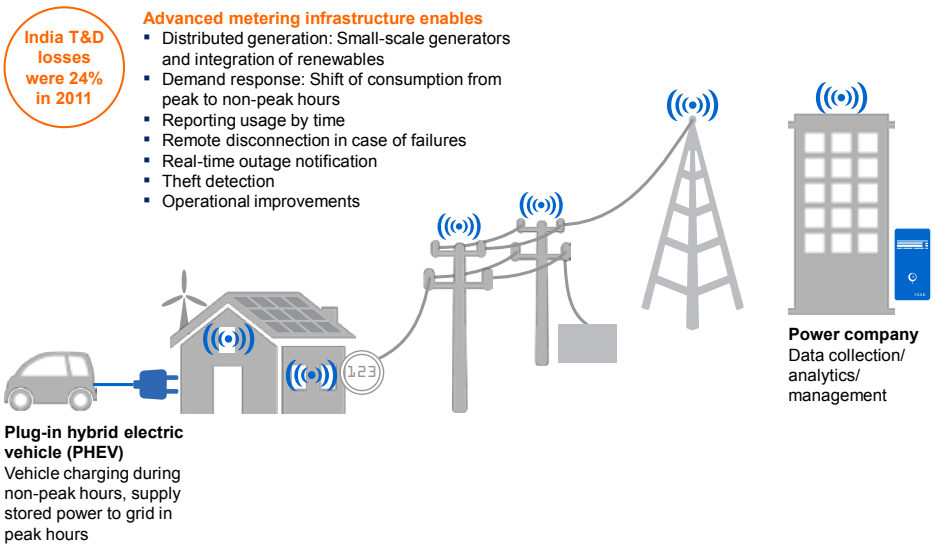
Further in the future are offshore solar and seaweed biofuel technologies. The world's first offshore solar plant, in Kagoshima prefecture in southern Japan, opened in 2013, providing 70 megawatts of capacity. Offshore solar involves many complex engineering and operational challenges but could be an option in India, where solar farms compete with agriculture for land. Finally, seaweed biomass, which is in a very early stage of development, could someday be a solution for places such as India that cannot devote farmland to biofuels production.

Smart metering

While there is range of smart grid technologies in use or under development around the world to manage electricity distribution, the most relevant technology for India between now and 2025 would most likely be smart metering (Exhibit 43). Smart meters gather minute-by-minute data about energy use and communicate that information automatically to a central office. This allows real-time monitoring of energy flows to detect surges, outages, and, most critically in India, theft of service. Fourteen smart metering pilots are under way in India. Tata Power Delhi Distribution Limited (formerly known as North Delhi Power Limited) has installed 30,000 smart meters in homes and commercial establishments that account for 60 percent of energy consumption. Total energy losses have been reduced from 53 percent in 2002 to about 11 percent today, according to Tata Power Delhi Distribution. In Andhra Pradesh, the Central Power Distribution Company has installed smart meters on a pilot basis, and in Chennai, the Tamil Nadu Electricity Board is testing smart meters to detect spikes in use, which are indicative of misuse. Wider adoption of smart meters is held back by several factors, including rapidly evolving technology; some 40 different types of smart meters are now available.

Exhibit 43

Advanced metering infrastructure can reduce transmission and distribution (T&D) losses


India T&D losses were 24% in 2011
Advanced metering infrastructure enables
Distributed generation: Small-scale generators and integration of renewables
Demand response: Shift of consumption from peak to non-peak hours
Reporting usage by time
Remote disconnection in case of failures
Real-time outage notification
Theft detection
Operational improvements
123
Power company
Data collection/ analytics/ management
Plug-in hybrid electric vehicle (PHEV)
Vehicle charging during non-peak hours, supply stored power to grid in peak hours

SOURCE: McKinsey Global Institute analysis

Advanced energy storage

Energy storage systems—batteries—are an important technology for improving the quality and reliability of the electric supply, integrating power from renewable energy sources such as wind and solar, and bringing electricity to unserved areas. On the grid, energy storage can be used to meet peak demand without the need to add extra generating capacity. On-grid storage also can be used to protect the network from fluctuations that can cause outages and to accommodate more solar and wind power in the electricity mix. These renewable energy sources are intermittent, and their production may not coincide with demand (solar panels, for example, produce power only when the sun shines).

As battery technology advances, energy storage can play an even larger role in bringing power to remote areas beyond the grid's reach. Currently, the high cost of storage is a big impediment to off-grid solar in rural villages; it costs Rs. 7 to Rs. 10 per kilowatt-hour to generate electricity with solar panels, but storage can double or triple total the cost. That is still less than using diesel or kerosene generators, but reduced storage costs could significantly drive adoption of solar in rural areas. In some parts of India, adoption is being driven by a leasing model, in which households rent a kit with a small solar collector and battery that provides enough electricity to charge cellphones and power a lamp and a radio. Globally, such setups could help bring electricity to an estimated 600 million people who now are not connected.[88]

Energy efficiency

Today, India has the highest energy intensity among major nations. Each dollar of GDP generated in the Indian economy requires 17,000 British thermal units of energy, about five times the Danish rate and 1.7 times the global average of 9,900 units. The United States requires just 7,700 British thermal units for each dollar of GDP.[89] India can reduce the additional energy that will be needed to support the 2025 population by raising the use of energy-efficient lighting and appliances, mandating use of more efficient water pumps, raising the efficiency of power plants, cutting transmission and distribution losses, investing in more efficient transportation equipment, and using more biofuels (Exhibit 44).

Exhibit 44
Energy-efficient technologies can help reduce energy use across sectors

Sector	Description	Possible interventions
Residential	▪ Buildings account for ~30% of electricity used in India ▪ Potential energy savings in new buildings is 40% or more	▪ Increase penetration of CFL/LED bulbs from current 10% in residential to 90% ▪ Increase penetration of BEE Star-labelled appliances from ~20% to 90%
Agriculture	▪ Pump sets account for ~20% of total agricultural energy demand	▪ Mandate use of BEE Star efficient pump sets for new connections ▪ Replace more diesel pumps with electric pumps
Power	▪ Inefficient power plants ▪ T&D losses are ~24%	▪ Use supercritical technology and other improvements to raise efficiency of coal plants from 38% to 41% ▪ Implement national smart grid to cut theft by up to 90%
Transport	▪ Fuel efficiency of Indian trucks is low ▪ Limited use of bio-ethanol fuel blend	▪ Investments in better technology for transportation ▪ Implement national biofuel policy to blend 5% bio-ethanol in petrol and diesel

SOURCE: India Energy Security Scenario 2047, Planning Commission, Government of India; US Energy Information Administration; McKinsey Global Institute analysis

88 *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

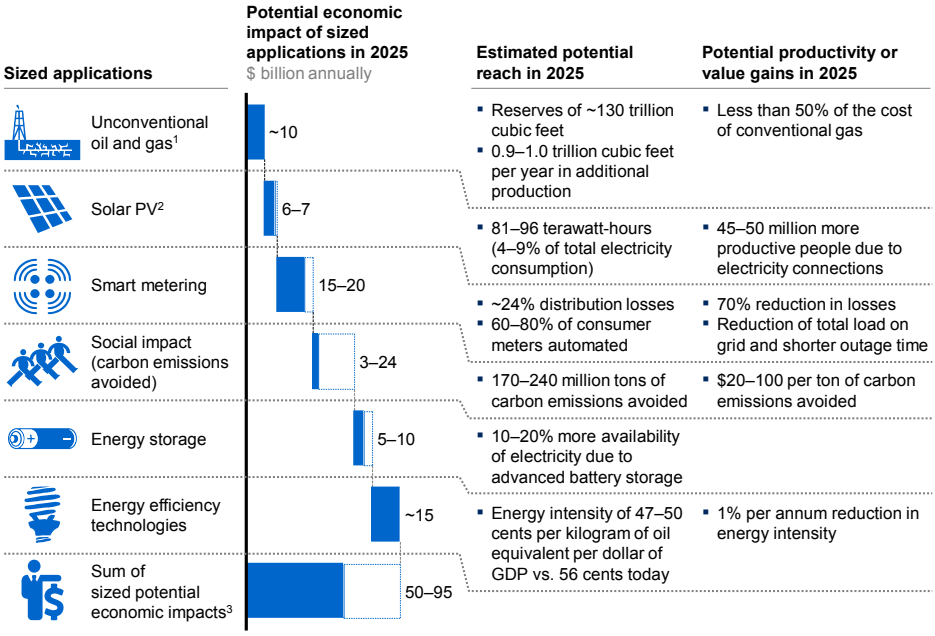
89 US Energy Information Administration.

POTENTIAL IMPACT

The combined economic impact of the energy technologies that we size could be $50 billion to $95 billion per year in 2025, including $3 billion to $24 billion in annual value from avoided carbon emissions (Exhibit 45). The technology with the largest potential impact is smart metering, which we estimate could save India $15 billion to $20 billion per year in 2025 in reduced transmission losses. This assumes that 60 to 80 percent of all consumer meters are automated and that transmission and distribution losses would be reduced by 70 percent. There would be additional savings from reduced load on the grid and shorter outages. The next-largest contribution would be from technologies that can increase the efficiency of energy generation and production. We estimate that India's energy intensity could be improved from 56 cents per kilogram of oil equivalent per dollar of GDP today to about 50 cents in 2025. Based on this estimate, energy-efficiency technologies could contribute some $15 billion of annual economic impact in 2025.

Exhibit 45

Selected technology-based applications in the Indian energy sector can have economic impact of $50 billion to $95 billion per year in 2025


Sized applications
Potential economic impact of sized applications in 2025
$ billion annually
Estimated potential reach in 2025
Potential productivity or value gains in 2025
Unconventional oil and gas[1]
~10
▪ Reserves of ~130 trillion cubic feet
▪ 0.9–1.0 trillion cubic feet per year in additional production
▪ Less than 50% of the cost of conventional gas
Solar PV[2]
6–7
▪ 81–96 terawatt-hours (4–9% of total electricity consumption)
▪ 45–50 million more productive people due to electricity connections
Smart metering
15–20
▪ ~24% distribution losses
▪ 60–80% of consumer meters automated
▪ 70% reduction in losses
▪ Reduction of total load on grid and shorter outage time
Social impact (carbon emissions avoided)
3–24
▪ 170–240 million tons of carbon emissions avoided
▪ $20–100 per ton of carbon emissions avoided
Energy storage
5–10
▪ 10–20% more availability of electricity due to advanced battery storage
Energy efficiency technologies
~15
▪ Energy intensity of 47–50 cents per kilogram of oil equivalent per dollar of GDP vs. 56 cents today
▪ 1% per annum reduction in energy intensity
Sum of sized potential economic impacts[3]
50–95

1 Potential economic impact estimated by calculating incremental gross output from 2025 production and prices, and converting into value added through GDP multiplier tables; currently estimated reserves are for information only.
2 Grid and off-grid solar PV combined.
3 Only direct value added. Indirect and induced impact, as well as downstream benefits, could nearly double the impact.
NOTE: Potential economic impact not comprehensive; includes potential impact of sized applications only. Numbers may not sum due to rounding.
SOURCE: India Energy Security Scenario 2047, Planning Commission, Government of India; US Energy Information Administration; McKinsey Global Institute analysis

Unconventional oil and gas might generate value of $10 billion per year in 2025, assuming that additional production from unconventional gas production reaches 900 billion to 1 trillion cubic feet per year and yields a savings of slightly more than 50 percent of the cost of imported sources. PV solar could account for $6 billion to $7 billion of electricity production per year, or 4 percent of electricity supply in 2025. Finally, energy storage could create $5 billion to $10 billion of annual impact in 2025, assuming it provides capacity equivalent to 5 to 10 percent of total electricity supply. We estimate that new energy technologies

could bring electricity to 80 million to 110 million more people by 2025 and avoid 180 million to 220 million tons of carbon emissions.

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

Each of the technologies faces challenges to implementation that will require the efforts of many stakeholders to address. Developing unconventional oil and gas and coal-bed methane in India will require advances in non-water fracking technologies as well as improvements in oil and gas supply chains. In PV solar, the obstacles include high capital requirements and a lack of knowledge. The smart metering effort is constrained by a number of factors, including a lack of financial capacity by operating companies to invest in widespread introduction of the technology. The technology itself is not yet mature, and there is no India-specific system. With supportive government policies and actions, India can take advantage of empowering technologies to develop new sources of energy, reduce dependence on imported fuels, curb carbon emissions, and bring electricity to tens of millions of people. Some actions that can be considered are:

Exploration and development

The government can support development of unconventional oil and gas projects by clarifying policies and codifying requirements for activities across the oil and gas value chain (such as standardising and publicising application and reporting requirements, as well as reviewing procedures). The Directorate General of Hydrocarbons can be strengthened into a quasi-independent body with the requisite financial and human resources to support development of unconventional oil and gas and streamline exploration and recovery projects. Norway assigned 350 people to its effort to jumpstart unconventional oil and gas development. Private- and public-sector players could be allowed to explore and develop any unconventional gas in blocks that have been designated under the New Exploration Licensing Policy.

Research and technical capabilities

The government can set clear rules for promoting research into technologies to reduce environmental impacts of energy development, such as advanced water treatment systems. Centres of excellence can be established at selected universities to promote solar R&D and education. Investments in GIS data could help identify potential locations for wind and solar farms. Similar investments in battery R&D are critical to make off-grid solutions a success. Technology vendors can provide critical support for the data analytics needed for successful fracking, perhaps by partnering with international players that have expertise in this area.

Funding and capital support

Import duties can be reduced on energy technologies such as equipment for unconventional oil and gas projects, smart metering, and renewables. Select energy industries can be recognised as priority industries, and banks could be encouraged to increase lending to such companies. The government can provide loan guarantees for solar manufacturing, for example. Given the sizable solar capacity planned, the government and the private sector could invest in global-scale poly-silicon manufacturing capabilities to reduce dependence on imported solar panels. State governments can designate state-owned land that can be made available for solar installations and facilitate long-term land leasing arrangements. Using wasteland areas (land considered unfit for farming) could help accelerate solar adoption and reduce costs by 10 to 15 percent.

Demand management

State electricity boards can evaluate rural electrification needs and aggregate them at the district level to invite bids for installation. To integrate rooftop solar into the power supply, boards can support purchases of necessary equipment by households and businesses and offer peak pricing for purchases of electricity from rooftop systems. Policy makers will need to work with electric companies and technology vendors to establish common data standards for smart meters and other smart grid devices, and use educational programmes to persuade consumers to accept smart meters in their homes.

7. Infrastructure

Around the world, nations face massive challenges to build and maintain infrastructure at sufficient levels to support economic growth and provide residents the elements of a decent lifestyle (affordable housing, access to clean water, sewerage, and transportation). India, like other developing economies, faces additional challenges, including severe financial constraints that limit its ability to fund infrastructure investment. New technologies and technology applications can play an important role in meeting India's challenges, helping wring more productivity out of existing infrastructure and enabling India to build new infrastructure more efficiently. In previous research, MGI has estimated that $1 trillion a year can be saved in infrastructure spending globally through use of new approaches and technologies to plan and manage new projects and better manage existing assets.[90] India can capture its share of those savings through a variety of initiatives and reforms. Here we focus on a set of emerging technologies, applications, and techniques that can help India address its infrastructure gap. Collectively, these could create economic impact of $30 billion to $45 billion a year in 2025.[91]

INDIA'S INFRASTRUCTURE CHALLENGE

The deficiencies in India's infrastructure—from inadequate roads and railways to insufficient water supplies—are well acknowledged. The extent and state of infrastructure in India is well below what is required to support economic growth, and without fresh approaches, that gap will only widen. We identify four specific challenges that India should focus on and which technology can help address.

Critical gaps in transportation infrastructure

At 3.8 kilometres per 1,000 inhabitants, India has one-tenth the road density of Australia and less than 20 percent of the US level. Its rail system is the fourth-largest in the world, covering 65,000 kilometres, but it suffers from decades of underinvestment.[92] India's 13 major shipping ports, along with numerous intermediate ports, handle more than seven million containers annually, but they are severely strained. Central government ports (12 of the 13 major ports) are working at 85 percent capacity, exceeding the ideal of 70 percent. Mumbai's Jawaharlal Nehru Port, the largest in India for solid cargo, works at over 100 percent of its ideal capacity. Capacity constraints are compounded by India's low level of containerisation, which at 25 percent is well below the global average of 60 to 70 percent. Furthermore, the average time for clearing import or export cargo at ports in India is about 19 days, compared with three to four days in Singapore.[93]

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90 *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013.

91 Our analysis takes in transportation, logistics, water systems, construction, and project management. We discuss opportunities to improve electric and telecommunications infrastructure in other chapters of this report.

92 *CIA factbook*, 2013.

93 worldshipping.org, holman fenwick willan (hfw).

Overall, Indian shipping suffers from reliance on obsolete technologies and from warehouse inefficiencies, which result in slow delivery times and high costs. Logistics in India consume 14 percent of the cost of goods, compared with 6 to 8 percent globally.[94] India's inadequate transportation infrastructure could be an increasingly significant drag on the economy: a committee appointed to frame the national transportation policy estimates that freight transportation needs will grow by a factor of six to seven over the next two decades. It estimates that passenger traffic will increase by a factor of five to six. This would be twice the growth rate of the past ten years.

Neglected urban infrastructure

India's cities face significant infrastructure deficits. Water supply per capita in India's cities is estimated at 105 litres per capita per day, compared with the norm of 135.[95] Only an estimated 30 to 40 percent of urban sewage is treated. Housing and roads are woefully inadequate: in peak periods, 50 percent more vehicles are on the road than the recommended norm.[96] The consequences of these infrastructure gaps are severe: poor water quality leads to disease and malnourishment, and motor vehicle pollution is linked to respiratory disease. If current trends persist, an estimated 18.8 million urban households will be affected by India's growing affordable housing gap (defined as families that cannot find decent housing or pay more than 30 percent of income for accommodations). Housing costs represents one-third of the unmet needs of urban Indians living below the MGI Empowerment Line.[97] Overcrowding in slums and security concerns lead to slow growth in urban-based industries that rely on rural labour migrating to cities

Poor execution of projects

India has struggled to deliver infrastructure projects on time and on budget, and projects have often fallen short of plans. In the 11th Five Year Plan period (2007–12), for example, the actual addition of road capacity was 32 percent lower than the target, port additions were 63 percent lower, and only half the 10,000 kilometres of rail lines that were targeted for gauge conversion were converted.[98] Delays and shortfalls are the result of many factors, including poor project management and lack of coordination across ministries and functions. Projects are also held back by delays in environmental and forest-use approvals.

94 *2013 global manufacturing competitiveness index*, Deloitte, January 2013.

95 Standard recommended by India's High Powered Expert Committee on Urbanisation to the Planning Commission and the Department of Drinking Water and Sanitation.

96 *India's urban awakening: Building inclusive cities, sustaining economic growth*, McKinsey Global Institute, April 2010.

97 Ministry of Housing and Urban Poverty Alleviation; *From poverty to empowerment: India's imperative for jobs, growth, and effective basic services*, McKinsey Global Institute, February 2014.

98 Planning Commission of India.

Lack of funding

India has not found the money to invest in repairing and extending critical infrastructure. To bring transportation infrastructure up to the level needed to support current GDP growth, annual spending on roads, ports, bridges, and other infrastructure would need to rise from about 2.7 percent of GDP (the rate from 2007 to 2012) to about 3.5 percent, which would mean total spending of $1.2 trillion from 2015 to 2025.[99] The government estimates that it would need about $250 billion from 2015 to 2025 to properly address slum renewal and water- and sanitation-related infrastructure needs.[100] The Planning Commission expects that at least 50 percent of India's infrastructure funding will come from the public sector, with the balance from private sources via public-private partnerships. However, government finances are constrained by efforts to reduce fiscal deficits, and private capital is not yet flowing since policies and mechanisms are not in place for the smooth functioning of private-public partnerships. In the absence of increased funding, India has an urgent need to get as much value as possible from every rupee spent on infrastructure.

TECHNOLOGY-BASED APPLICATIONS AND SERVICES

We identify six technology developments and applications that can help India narrow its infrastructure gap (Exhibit 46). These technologies and applications can increase the capacity of existing infrastructure and both speed up and reduce the cost to complete infrastructure projects.

Exhibit 46
Six technology-based solutions to improve India's infrastructure

Smart cities	Technology-based and data-driven urban planning and management approaches to improve energy efficiency, efficiency of public services, and quality of life; enabling economic growth	**Intelligent freight logistics**	A range of technologies and applications (such as container number recognition and RFID tags) to track freight and manage the flow of cargo
Smart highways	Internet of Things technologies such as sensors and cameras to monitor traffic flow, making possible real-time congestion planning, automated toll-collection, and access control	**Advanced water treatment systems**	Nanofiltration and zero-liquid discharge to remove harmful dissolved solids, reduce effluent discharge in water, and enable wastewater reuse
Next-generation construction methods	Adoption of new methods and materials such as prefabricated cast concrete to improve efficiency of infrastructure construction and other types of building	**IT-enabled project management systems**	Modern IT systems to manage infrastructure projects and eliminate inefficiencies in procurement and other processes

SOURCE: McKinsey Global Institute analysis

99 *India transport report: Moving India to 2032*, National Transport Development Policy Committee, Planning Commission, Government of India, 2014.

100 *Report on Indian urban infrastructure and services*, High Powered Expert Committee for Estimating the Investment Requirements for Urban Infrastructure Services, March 2011.

Smart cities

The term “smart cities” refers to an integrated set of technology-based and data-driven urban planning and management tools aimed at improving energy efficiency, making public services more efficient, improving quality of life, and enabling economic growth. They include energy-efficiency measures such as green building technology and rooftop solar, as well as smart water metering to detect leaks and quality problems. Some smart cities are using advanced sewage processing techniques to convert municipal waste to fuel for generating electric power. Many smart cities use big data analytics for congestion planning and to adjust traffic speeds and mix. Smart city transportation applications also include smart ticketing (using electronic cards as tickets for public transportation) and fare systems for multimodal transportation. Other transportation applications include bicycles and car-sharing. Smart cities offer transparent and convenient citizen services, such as digital property records and transfers, e-payment of local taxes, emergency and security services centrally monitored using mobile technology, and public health monitoring (Exhibit 47). Providing infrastructure for the digital economy, including broadband connectivity and well-planned spaces for data centres and knowledge-based enterprises, is another way smart cities enable economic activity.

Exhibit 47
Examples of smart cities investments

Barcelona
- Telecommunications: new network integrates different fibre optic networks, boosting Wi-Fi network
- Smart parking: network of sensors and displays of parking availability across the city
- Transport and energy efficiency: electric vehicles, orthogonal bus network

Boston
- Participatory urbanism: platforms for citizens to give feedback and input on government initiatives
- Clicks and bricks: links how the city is built to how it is managed and experienced
- Open data: sharing government data sets to spark innovation/new businesses

Chicago
- Internet: significant infrastructure investment to create high-speed broadband access for all citizens
- Open data: systems have spawned businesses and applications (Health Atlas, which aggregates and maps health-related information on a map)

Hong Kong
- E-government: 49 government mobile applications and 38 mobile websites
- Government Wi-Fi: goal to transition Hong Kong into a wireless city, with free Internet service to all citizens
- Open data: demographic, economic, geographic, and meteorologic data, historical documents, and archives made available to the public

Rio de Janeiro
- City services: centre of operations helps the city manage resources and improve efficiency of response
- Open data: programmes to help circulate information and facilitate the flow of information

Stockholm
- E-government: more than 50 digital services
- Stokab Fiber Network: expansion of high-speed Internet access, environment for IT development
- Kista Science City: a forum for companies, researchers, and students to collaborate on technology projects
- Transport and energy efficiency: big data scheme to optimise performance

SOURCE: McKinsey Global Institute analysis

Many countries, including China, France, the Netherlands, Singapore, and the United Kingdom, have implemented multimodal urban transportation systems that offer seamless electronic ticketing options, which encourage use of public transit. In India, technology could be used for additional purposes that promote road safety, such as educating drivers on traffic rules and introducing smart licences with chips that retain the driver’s history.

Supervisory control and data acquisition systems that communicate with remote sensors are being used in urban water and wastewater management to monitor corrosion of pipelines, significantly improving operating efficiencies by avoiding breakdowns. Bengaluru, India's third-largest city, plans to implement such a system to monitor its water distribution network starting in 2015, and then expand it to monitor wastewater treatment facilities.

China has made a large commitment to smart cities technologies and approaches, which are being piloted in 193 cities as part of an urban renewal plan. India is starting a similar programme, with $1.2 billion allocated to 100 cities. Smart city concepts can help India build economically vibrant, globally connected urban centres beyond its megacities—in both smaller cities and outlying areas of major cities.

Intelligent freight logistics

Intelligent freight systems fall under intelligent transportation and distribution systems, one of our 12 focus technologies. This includes a range of technologies and applications that make it possible to track freight wherever it goes and manage the flow of raw materials, parts, finished goods, and imports and exports. In India, the opportunity to implement intelligent logistics has been limited by the adoption of standard shipping containers. Currently, 50 to 60 percent of Indian freight is containerised, significantly less than in developed economies and China.

Freight that is in containers marked with CNR (container number recognition) symbols—a large-format barcode—can be scanned and tracked electronically, speeding up processes at terminals and avoiding errors. RFID tags—inexpensive tags with data about the identity and contents of a container—are also commonly used to track containers, pallets, and individual products as they flow through logistics systems. RFID-based terminal automation systems, which monitor RFID-tagged vehicles and equipment as well as cargo, plan the flow of cargo, assets, and vehicles across terminals in real time. The system collects data that can also be used to automate yard management and planning, berthing management, and scheduling. An intelligent port system can reduce the turnaround time for loading and unloading cargo by 50 percent and significantly reduce operating costs (Exhibit 48). RFID-enabled smart freight systems are also being deployed for warehouse automation: automated load picking, online capacity planning and booking, optimised storage design, and inventory management.

China has adopted RFID technology on a large scale, and almost all its major ports use RFID-enabled terminal automation systems. Since the implementation of a smart freight system at the Port of Hong Kong, turnaround time for container vessels there has been reduced to ten hours from 40 to 45 hours.[101] The RFID system at the Port of Shanghai includes electronic seals on containers and handheld devices with GPS that port workers use for security and to marshal container trucks. Even though Shanghai is the world's busiest port, the RFID technology helps it turn around ships in one-third the time of traditional ports.[102]

In the Port of Georgia in the United States, an automated terminal asset management system was employed for remote recognition and tracking of trucks and containers, wireless transmission of data to vehicles, and other gate and yard

101 Press release on Port of Hong Kong, 2013.

102 Port of Shanghai website.

operations (Exhibit 49). As a result, truck turnaround time fell by an average of 10 to 11 percent per call, gate-trouble transactions were reduced from 10 percent to 3 percent, truck queues at the gate were eliminated, and workers were reassigned from the gate and yard to other work.[103]

In India, RFID has been deployed at the Port of Mundra in Gujarat to track vehicles at the gate, increase loading and unloading efficiency, and reduce errors. The technology is credited with reducing labour costs and raising efficiency by 50 percent.[104]

Exhibit 48
How intelligent systems can speed up shipping and logistics

RFID installed on individual containers and ships
- Scheduling
- Unloading
- Customer updates

RFID in terminal operations
- Yard planning and management
- Warehouse and storage automation

RFID transponders on trucks
- Ensures security and prevents theft
- Track container location in the yard or warehouse
- Flow-through gate system—fully automated system identifies container trucks and gives drivers instructions within 25 seconds

SOURCE: McKinsey Global Institute analysis

Exhibit 49
Automatic terminal management deployed at Port of Georgia to increase efficiency

- Active 915 Mhz RFID reader fitted to truck as it enters the terminal facility
- Intelligent readers with a range of 300 feet, installed at gates and in the yard, verify the details of the truck and its cargo and keep track of the vehicle

- The truck ID is sent to the terminal operations system, where it gets associated with the correct container number

- Instructions to load/offload are sent to the crane operator
- Forklifts and cranes are fitted with RFID interrogators that check the vehicle ID before loading or unloading

SOURCE: McKinsey Global Institute analysis

103 *Case study: Georgia Ports Authority*, Identec Solutions, 2012.

104 "RFID reduces traffic delays at Indian port," *RFID Journal*, July 2013.

Smart highways

National highways represent 2 percent of the total road network in India but accommodate more than 40 percent of the traffic.[105] The result is congestion: the average truck speed is 30 to 40 kilometres per hour (about half the global average). The traffic fatality rate is 18 per 100,000 people, more than twice the eight per 100,000 in advanced economies.[106]

Clearly, highway network expansion should be a long-term goal for India, but in the near term smart highway technologies can be used to raise road capacity and improve safety. Smart highways use Internet of Things technologies such as traffic sensors to manage the flow of vehicles. A system of sensors and cameras, for example, can monitor traffic flow, making possible real-time congestion planning. If congestion is detected, electronic message boards can be used to adjust speed limits and provide information on alternate routes, expected travel time, and causes of delays. Such systems also enable automated toll collection and access control. London uses cameras linked to automatic licence-plate readers to enforce its congestion pricing policy, which has reduced congestion by 30 percent in peak period traffic times.[107]

On England's M42 motorway, smart highway technology has been used to optimise traffic flow and reduce average journey time by 25 percent. Since the system was installed in 2006, the rate of accidents has fallen by more than 50 percent, pollution is down 10 percent, and fuel consumption has been reduced by an estimated 4 percent. The project was completed at a cost of $170 million in two years; by McKinsey estimates, an alternative road widening plan would have taken $850 million and ten years to complete.

In Brazil, the city of São Paulo has invested in smart highway technologies, including a real-time adaptive traffic control system at 382 intersections. The system, using cameras and licence-plate recognition, monitors the flow of traffic and optimises the flow to reduce congestion during peak traffic times (when only motorists who have paid congestion charges are allowed in certain districts). The city says that these technologies have reduced congestion by 18 percent in restricted areas, cut journey times by 14 percent, and reduced accidents and emergencies by 31 percent (Exhibit 50).

Automated tolling has many advantages, including significant labour savings and reduced congestion. In India, where toll payments are typically made in cash, switching to electronic toll payment also would reduce leakage and increase government revenue. Automatic electronic tolling—using RFID tags or transponders installed on cars or cameras and licence-plate readers—has been adopted widely in Japan, Singapore, Taiwan, the United States, and other countries. In India, a few tolls have e-toll capability (for example, the Rajiv Gandhi Sea Link in Mumbai). These toll booths still have gates, unlike the latest systems in other countries, which do not require the vehicle to stop or, in some cases, to even slow down.

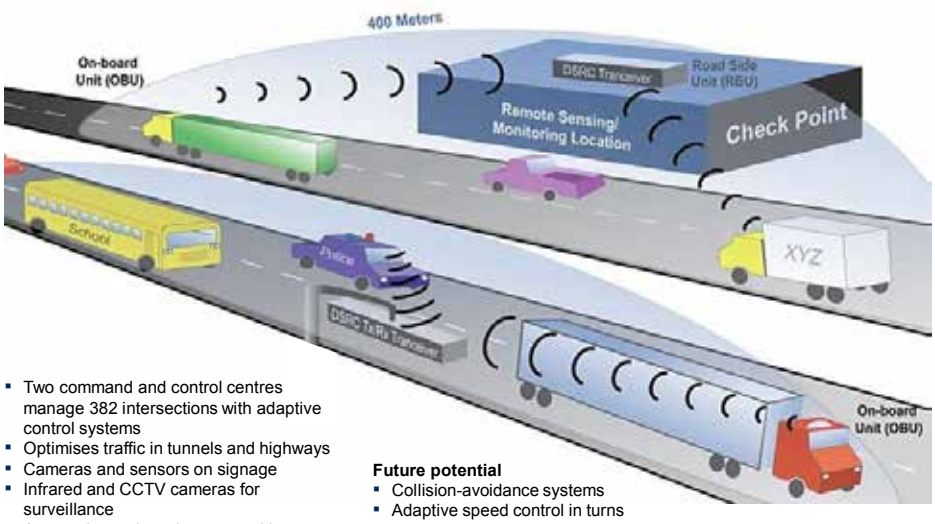
105 National Highways Authority of India.

106 *Global status report on road safety 2013*, World Health Organization, March 2013.

107 *Active traffic management: Innovative techniques for the future*, Washington State Department of Transportation, September 2007.

Exhibit 50

São Paulo has used smart highway technology to reduce congestion and traffic casualties



- Two command and control centres manage 382 intersections with adaptive control systems
- Optimises traffic in tunnels and highways
- Cameras and sensors on signage
- Infrared and CCTV cameras for surveillance
- Automatic number-plate recognition to enforce limited access rules and reduce congestion

Future potential

- Collision-avoidance systems
- Adaptive speed control in turns and near adverse road conditions
- Making emergency assistance readily available

SOURCE: www.cendi.gov/presentations/IPv6_Dec_2007_Schmidt.pdf; McKinsey Global Institute analysis

Advanced water treatment systems

Advanced water treatment technologies are being used to remove harmful dissolved solids in water supplies, reduce effluent discharge in water, and enable wastewater reuse. In India, which plans to invest more than $25 billion in water supply and sanitisation over the next three years, these technologies can make important contributions.

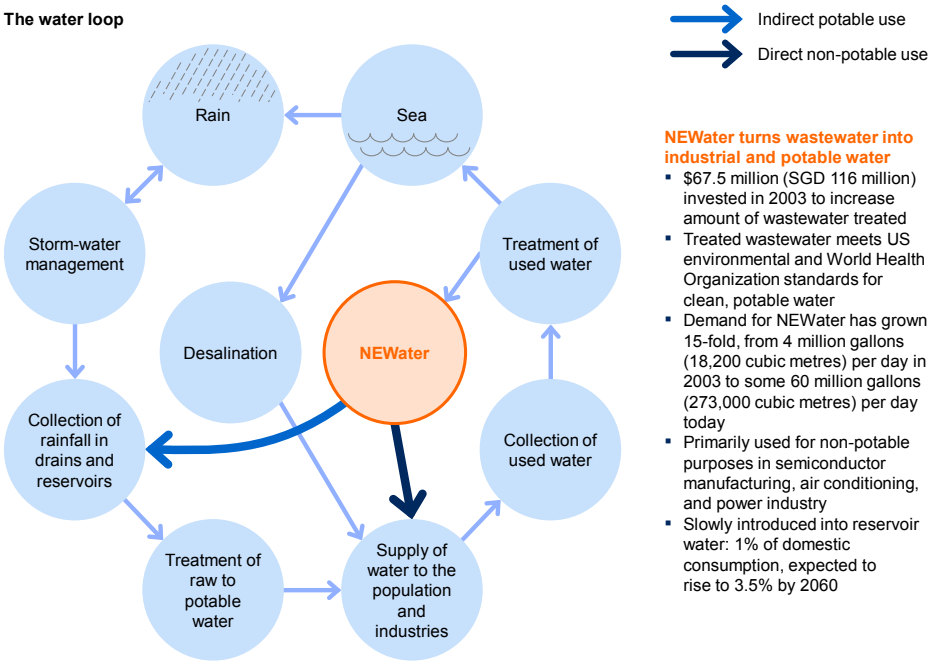
One of the most promising technologies in water treatment is nanofiltration, a membrane filtration process used most often to treat surface water and fresh groundwater. It uses membranes to remove dissolved solids such as pollutants, is relatively inexpensive, and, unlike other water purification techniques, does not strip out essential minerals such as calcium. Nanofiltration is used in Israel in water purification and industrial water treatment and recycling. India is adopting this technology in its effort to remove pollution from the Ganga, one of the largest and most polluted rivers on the planet. A $1 billion World Bank project to rehabilitate the Ganga brings together Israeli clean-tech companies and Indian partners.[108]

108 Israel21c.org.

Water reuse is the process of reclaiming used water by removing contaminants from wastewater, including household sewage and runoff. The objective is to produce an environmentally safe fluid waste stream and a solid-waste byproduct that is suitable for disposal or reuse. With some technology, it is even possible to reuse sewage effluent for drinking water. This is already done by Singapore's public utilities board, which has pioneered water reuse to reduce reliance on imports. Some 30 percent of freshwater demand is filled by the NEWater reclamation facility (Exhibit 51).[109] By 2060, Singapore plans to triple its NEWater capacity to meet up to 55 percent of demand.

Zero liquid discharge is a treatment system that is being adopted to treat water used in industry before it is released back into streams and other waterways. The process removes dissolved solids, and reverse osmosis also may be used to concentrate a portion of the waste stream. The Punjab Pollution Control Board has facilitated the installation of zero liquid discharge systems in eight electroplating plants, and approximately 500 small-scale electroplating industries have established a cooperative to treat their effluent with this technology. Since 2009, the Andhra Pradesh State Board has promoted implementation of zero liquid discharge mainly for pharmaceutical industries that are located in clusters of industrial estates in and around Hyderabad city.

Exhibit 51
Singapore fills 30 percent of its water needs with reused water


The water loop
Indirect potable use
Direct non-potable use
Rain
Sea
Storm-water management
Treatment of used water
Desalination
NEWater
Collection of rainfall in drains and reservoirs
Collection of used water
Treatment of raw to potable water
Supply of water to the population and industries
NEWater turns wastewater into industrial and potable water
$67.5 million (SGD 116 million) invested in 2003 to increase amount of wastewater treated
Treated wastewater meets US environmental and World Health Organization standards for clean, potable water
Demand for NEWater has grown 15-fold, from 4 million gallons (18,200 cubic metres) per day in 2003 to some 60 million gallons (273,000 cubic metres) per day today
Primarily used for non-potable purposes in semiconductor manufacturing, air conditioning, and power industry
Slowly introduced into reservoir water: 1% of domestic consumption, expected to rise to 3.5% by 2060

SOURCE: Public Utilities Board, Singapore; World Bank; McKinsey Global Institute analysis

109 Singapore Public Utilities Board.

Next-generation construction methods

India can greatly improve the efficiency of infrastructure construction and other types of building by adopting new methods and materials, such as prefabricated cast concrete. Large concrete components are fabricated offsite and transported to the construction site, where they are assembled to create the superstructure. In most situations this is faster and cheaper than pouring concrete on-site and results in higher quality since components are constructed in a controlled factory setting using the latest technologies, such as 3D modelling. In buildings, precast parts can include embedded mechanical, electrical, and plumbing connections, reducing the labour time needed to install those systems.

Another construction innovation is tunnel form, a formwork system that enables the casting of horizontal and vertical elements simultaneously. Walls and slabs can be cast in one operation in a daily cycle. This approach combines the speed, quality, and accuracy of off-site production with the flexibility of on-site construction.

In India, next-generation construction methods have particular import for fulfilling the government's goal to ensure that every Indian family can have a house of its own by 2022. The Ministry of Housing and Urban Poverty Alleviation estimates that affordable housing accounts for 17.8 million units of the nation's 18.7 million-unit housing deficit.

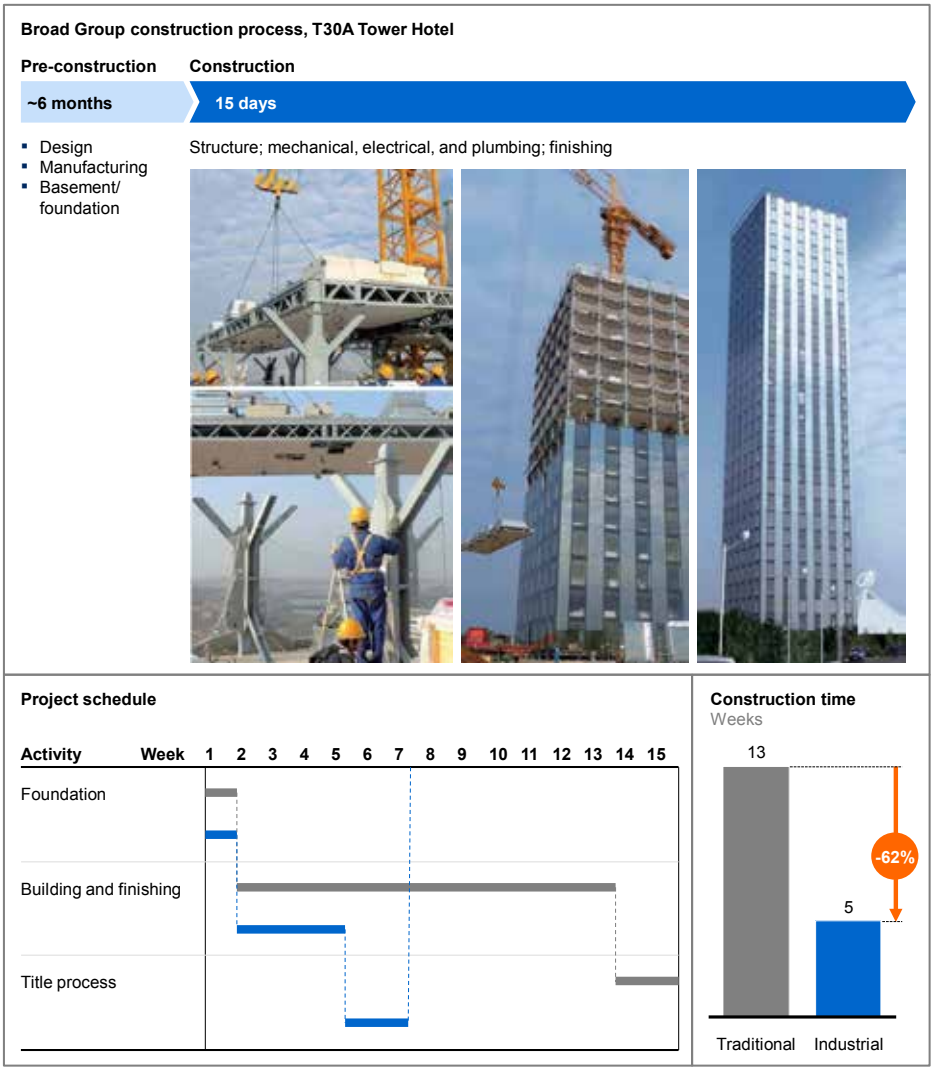
In advanced economies, construction costs have been cut by as much as 35 percent through a combination of prefabrication and value engineering, according to McKinsey research. Project completion times for low-cost homes can be reduced to 15 months from 24 months, using prefabrication and tunnel-form casting. Bauhu Homes, a UK construction company that specialises in prefabrication technology, has delivered affordable homes for as little as $311 per square metre (compared with an average cost of $650 per square metre using conventional techniques in the United Kingdom). A US-based architecture firm, KieranTimberlake, aims to use prefabrication technology to build houses in India at a target cost of Rs. 9,500 to Rs. 12,000 per square metre ($160 to $200), or more than one-third less than the cost of current affordable housing.[110]

In larger buildings, Broad Sustainable Building, a subsidiary of China's Broad Group, is pioneering large-scale construction using prefabricated parts. It built the six-story Broad Pavilion at the 2010 Shanghai Expo trade show in one day. The same year, it built the 15-story New Ark Hotel in six days and a 30-story hotel prototype in 15 days, both near Dongting Lake in Hunan Province (Exhibit 52). The prototype was assembled by using a diagonal steel branching system.

110 Based on Ministry of Housing and Urban Poverty Alleviation estimates.

Exhibit 52

Broad Group has used prefab components to build a 30-story hotel in just 15 days



SOURCE: Broad Group; expert interviews; McKinsey Global Institute analysis

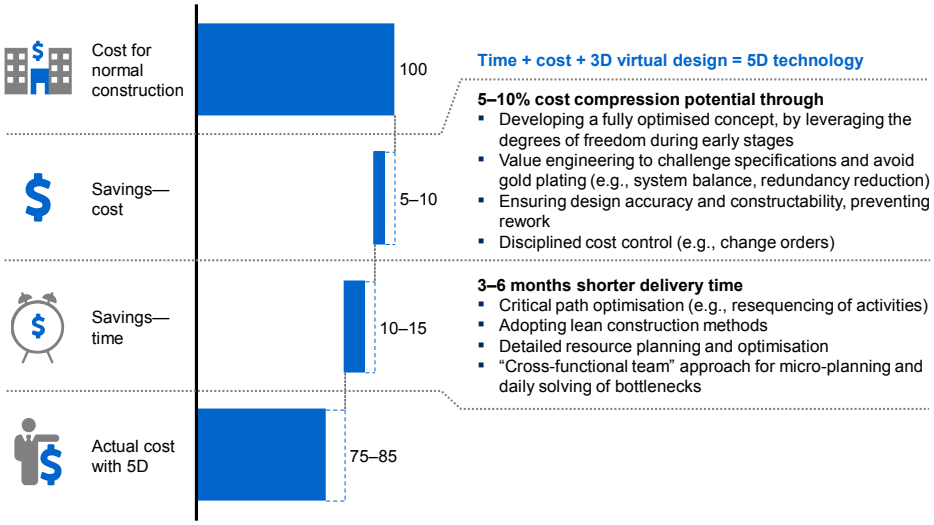
IT-enabled project management systems

There are enormous savings to be gained through use of modern IT systems to manage infrastructure projects. We estimate that the cost of inefficiencies in implementing infrastructure projects, including awarding projects as per the five-year plan targets, securing financing, and not completing projects within cost and time targets, could be $200 billion from 2009 to 2017.[111] An emerging type of IT system, 5D Building Information Modeling (5D BIM), is a significant technological advance that links 3D design drawings with the additional dimensions of time and cost, enabling architects, builders, and other stakeholders to monitor every aspect of a project. It is estimated that these systems could yield a 15 to 25 percent improvement through project cost savings (Exhibit 53).[112]

Exhibit 53

New 5-dimension design and construction management technology typically reduces costs by 15 to 25 percent and can save 3–6 months

Project cost (normalised to 100)


Cost for normal construction
100
Savings—cost
5–10
Savings—time
10–15
Actual cost with 5D
75–85
Time + cost + 3D virtual design = 5D technology
5–10% cost compression potential through
Developing a fully optimised concept, by leveraging the degrees of freedom during early stages
Value engineering to challenge specifications and avoid gold plating (e.g., system balance, redundancy reduction)
Ensuring design accuracy and constructability, preventing rework
Disciplined cost control (e.g., change orders)
3–6 months shorter delivery time
Critical path optimisation (e.g., resequencing of activities)
Adopting lean construction methods
Detailed resource planning and optimisation
"Cross-functional team" approach for micro-planning and daily solving of bottlenecks

SOURCE: Thenbs.com; McKinsey Global Institute analysis

POTENTIAL IMPACT

To gauge the potential impact of new technologies in Indian infrastructure, we look at the potential for savings in four areas: roads and highways; ports and warehousing; water and sanitation; and improved project management and delivery. We estimate that if the technologies and applications we outline here are adopted and implemented in India, they could have a combined annual economic impact of $30 billion to $45 billion in 2025. Our estimates assume that these technologies would help raise the operational efficiency of existing infrastructure systems—highways, logistics, and water management systems—reducing annual spending needed in these areas by 17 percent. We also assume that these techniques would be used in 18 percent of assets by 2018.

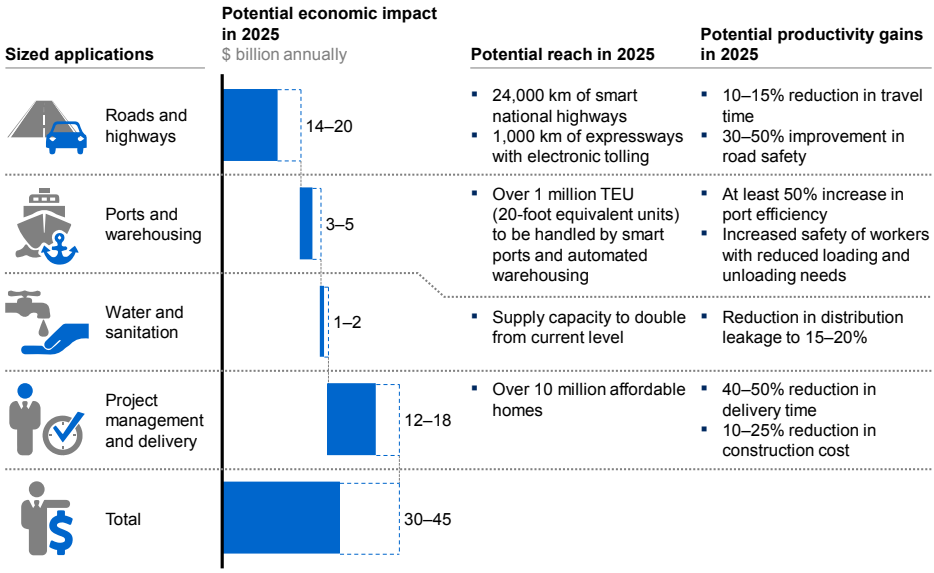
111 *Building India: Accelerating infrastructure projects*, McKinsey Infrastructure Practice, August 2009.

112 Expert interviews; Thenbs.com.

Modern construction and project management technologies could enable savings of $12 billion to $18 billion per year in 2025 (Exhibit 54). We estimate savings on new projects at 23 to 29 percent and savings on renewal projects at 12 to 15 percent. We base our estimates of economic value on cost savings and productivity gains. In addition, these technologies can generate societal benefits as well. Road safety could be raised by up to 50 percent, port workers would be safer, and less untreated sewage would wind up in rivers and streams.

Exhibit 54

Infrastructure technologies can deliver economic value of $30 billion to $45 billion per year in 2025


Sized applications
Potential economic impact in 2025
$ billion annually
Potential reach in 2025
Potential productivity gains in 2025
Roads and highways
14–20
24,000 km of smart national highways
1,000 km of expressways with electronic tolling
10–15% reduction in travel time
30–50% improvement in road safety
Ports and warehousing
3–5
Over 1 million TEU (20-foot equivalent units) to be handled by smart ports and automated warehousing
At least 50% increase in port efficiency
Increased safety of workers with reduced loading and unloading needs
Water and sanitation
1–2
Supply capacity to double from current level
Reduction in distribution leakage to 15–20%
Project management and delivery
12–18
Over 10 million affordable homes
40–50% reduction in delivery time
10–25% reduction in construction cost
Total
30–45

SOURCE: Broad Group; expert interviews; McKinsey Global Institute analysis

ADDRESSING BARRIERS TO TECHNOLOGY ADOPTION

Adopting the technologies to narrow India's infrastructure gap is not a simple, straightforward process. Many obstacles stand in the way, the foremost of which is securing funding. Given the limitations of government finances, India will likely need to cultivate private sources of capital to fund infrastructure investments. Before private funding can be expected to flow into infrastructure projects, the government would need to take steps to improve the overall business environment and establish frameworks for public-private partnerships. Another major challenge in India is the lack of capability in government planning agencies to identify and evaluate the right technologies. As it considers technology approaches to infrastructure, India would benefit from the input of an expert panel to evaluate the potential technologies and prioritise the projects that would have the greatest impact on infrastructure.

Multinational infrastructure developers, with their technology and experience in implementation, may be best equipped to bring cutting-edge technologies to India. However, due to various structural challenges, foreign direct investment in Indian infrastructure is fairly limited and is barely present in sectors such as highways, and residential and commercial construction. Addressing barriers to foreign direct investment in infrastructure could help speed the introduction of new technologies.

Similarly, execution capabilities remain a major limitation. Special-purpose entities, perhaps using private as well as public resources, could be empowered to execute specific projects—with the authority for “single-window” regulatory clearances and dispute resolution, overcoming common execution obstacles. A centralised government committee that monitors real-time progress of top-priority projects as they are implemented in various states could greatly accelerate the adoption of new technologies in Indian infrastructure.

To encourage technological advancement, government could switch to a bidding system that takes into account technical issues as well as cost. One such bidding method is the Swiss Challenge, under which a private player makes an unsolicited bid to the government, usually based on an innovation that the bidder has developed. The government, taking into consideration the technological bid, then calls for bids from the other players (the “challengers”) to ensure cost efficiency. Beyond adopting the Swiss Challenge, India can introduce new techniques and technologies into its projects by setting minimum technical criteria in conventional bid proposals.

Finally, success in adopting new approaches will require stakeholder engagement. Infrastructure projects affect a wide range of stakeholders and can often face resistance. It would help to communicate the significant non-economic benefits that infrastructure improvements would bring to the public: clean water, cleaner air, fewer traffic deaths, and an opportunity to solve India’s housing problem.

8. Government services

Around the world, governments are investing in technology-based services that are known collectively as e-government. These systems not only boost government efficiency, but they also promote openness and engagement by putting services and information online and allowing citizens to complete basic transactions such as applying for licences, passports, and benefits. A successful e-government effort helps deliver vital services more effectively and can also enable many disruptive technology-based applications for other sectors (providing GIS data for precision farming, for example). From implementations around the world, we see that e-government can promote innovation, by both private- and public-sector players, across a wide range of products and services. India has made a significant commitment to e-government and has been actively pursuing an e-government strategy since 2006. In this chapter we look at the current state of e-government in India and suggest how the nation might achieve more.

TECHNOLOGY-BASED APPLICATIONS FOR E-GOVERNMENT

Technology-based applications for e-government can be grouped into six areas (Exhibit 55).

Exhibit 55
Putting government data and services online can create value in six ways

Government efficiency initiatives	Using IT systems to raise the productivity and effectiveness of government operations such as tax collection	**Online citizen services**	Direct access to government information; self-service transactions, such as obtaining birth and death certificates, registering land, and applying for a passport
Online business services	Simplified online processes to obtain business licenses, pay taxes, and comply with regulations	**Connections to other governments**	Enabling effective collaboration across borders (interoperable digital identities and electronic visas, for example)
Open data	Sharing government data sets (land records, geological data, demographics, GIS data) to enable new applications, products, services, and business models	**Enabling infrastructure and technology platforms**	Hardware, connectivity, and software platforms (such as wide area networks, servers, and cloud) to offer e-government services

SOURCE: McKinsey Global Institute analysis

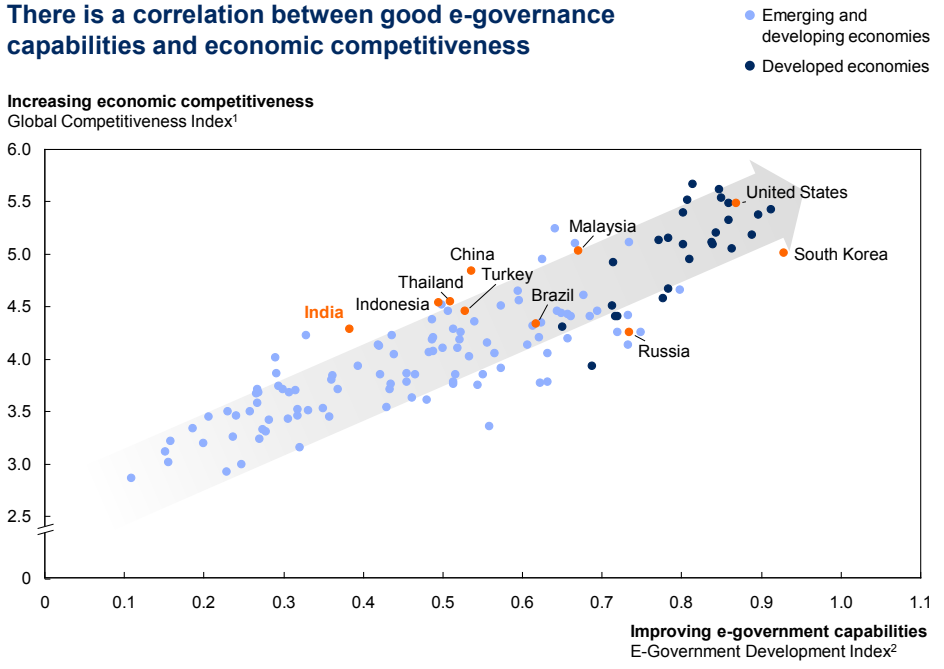
The Indian government's National e-Governance Plan (NeGP) was launched in 2006 to "… make all government services accessible to the common man in his locality, through common service delivery outlets".[113] The mission has been expanded to cover a broad range of government work, and 31 "mission mode projects" have been launched, including online passport services, e-health and e-education efforts, e-procurement, digitisation of land records, e-administration, a portal for business services, and a national identity system. To provide basic digital infrastructure at the national and state levels, eight e-government support components have been planned, to be built through technical and financial partnerships with the private sector.

POTENTIAL IMPACT

We do not size the potential economic impact of e-government separately since its true potential is hard to estimate. Rather, efficient government services can create economic value across all sectors by enhancing the competitiveness of the entire economy. The correlation between a country's overall economic competitiveness and its e-government capabilities is extremely strong (Exhibit 56). This is because effective e-governance can strengthen factors that determine competitiveness, such as well-functioning public institutions, high-quality human capital, efficient markets, and adequate infrastructure.[114] Online government systems, for example, can improve competitiveness by reducing the burden on businesses to make tax payments, apply for licences, and comply with regulatory requirements.

Exhibit 56

There is a correlation between good e-governance capabilities and economic competitiveness



1 The Global Competitiveness Index, in *Global competitiveness report , 2013–14*, World Economic Forum, September 2013, is based on 12 pillars including infrastructure, education, and labour market.
2 The E-Government Development Index, in *E-government survey 2012: Government for the people*, United Nations, February 2012, is based on services, infrastructure, and human capital.
SOURCE: World Economic Forum; United Nations; McKinsey Global Institute analysis

113 National eGovernance plan, www.india.gov.in.

114 For a comprehensive description of the Global Competitiveness Index, see *Global competitiveness report, 2013–14*, World Economic Forum, September 2013.

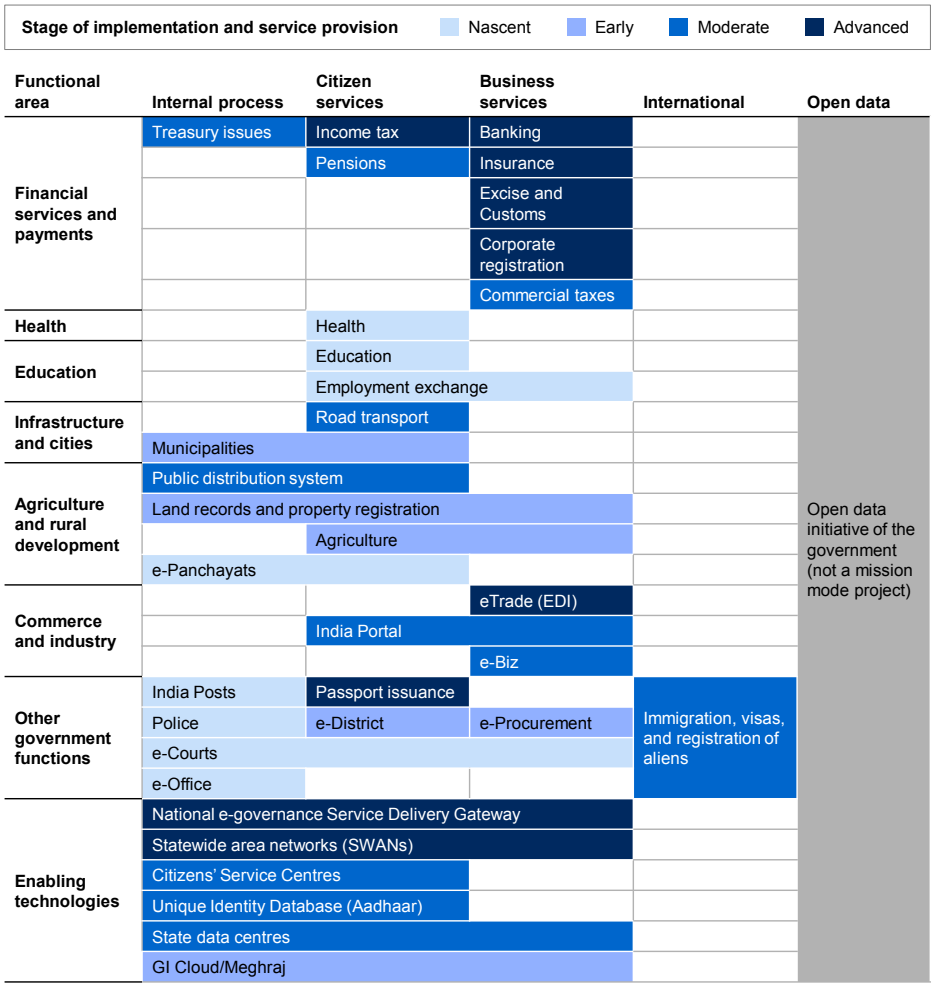
If India's e-government initiatives are successful, they can have wide-ranging impact on the economy and on the quality of life. Digital identity and digital payments initiatives make possible the efficient delivery of government benefits, remote health-care services, and distance learning. Overall, the effect would be to help reduce poverty by getting benefits to those in need, promote financial inclusion, reduce illness and prolong lives, and build greater skills in the labour force. All these improvements are associated with higher productivity and rising living standards. In the transportation sector, e-government efforts such as digitisation of ports, computerisation of PDS, and implementation of electronic tolling can help build efficient logistics and distribution networks. Finally, e-government can help reduce corruption in public services and strengthen the foundation of legal and administrative institutions.

Additional economic benefits from e-government initiatives come from opening up and sharing government data, which can benefit many sectors of the economy. Digitised land records, for example, can be integrated with data gathered on weather, soil conditions, crop yields, and rainfall to enable precision farming and raise agricultural productivity. Digital land records used in combination with geological data can help developers of shale-gas projects speed up the process of locating drilling sites, securing rights, and obtaining permits. Open data can also help speed up the process of finding sites for wind and solar projects and enable health applications such as disease mapping and clinical care decision support (using massive amounts of patient data to identify the most effective treatments, for example).

HARNESSING THE POTENTIAL

With all these potential benefits, having an effective e-government road map is no longer an option for an aspiring country—it is a necessity. India has recognised this and is pursuing an ambitious e-governance agenda. The challenge now is in execution. As can be seen in Exhibit 57, India has made good progress in implementing some of the 31 mission mode projects and has installed some critical infrastructure elements. Statewide networks have been rolled out in most states; 16 state data centres and three national data centres are operational; and more than 100,000 common services centres (which offer Web-based government services in rural areas) have been opened around the country. By May 2014, more than 3.45 billion e-government interactions had been logged as Indians obtained birth and death certificates; renewed driver's licences; registered land transactions; made tax, utility, and pension payments; retrieved information on agricultural prices; and received welfare payments. However, participation and citizen engagement are still held back by the difficulty of using many online systems, inadequate telecom infrastructure, and the lack of computer literacy across India, particularly in poor rural communities.

Exhibit 57
Select Indian e-government projects



SOURCE: Department of Electronics and Information Technology; government websites; expert interviews; McKinsey Global Institute analysis

Today, more than half of the mission mode projects are not yet fully operational. Some are at very early stages of implementation, and in some cases the project details have not even been approved. Some projects do not provide the full range of services envisaged. To date, services that have been launched in such high-value areas as agriculture, education, and health are particularly limited.

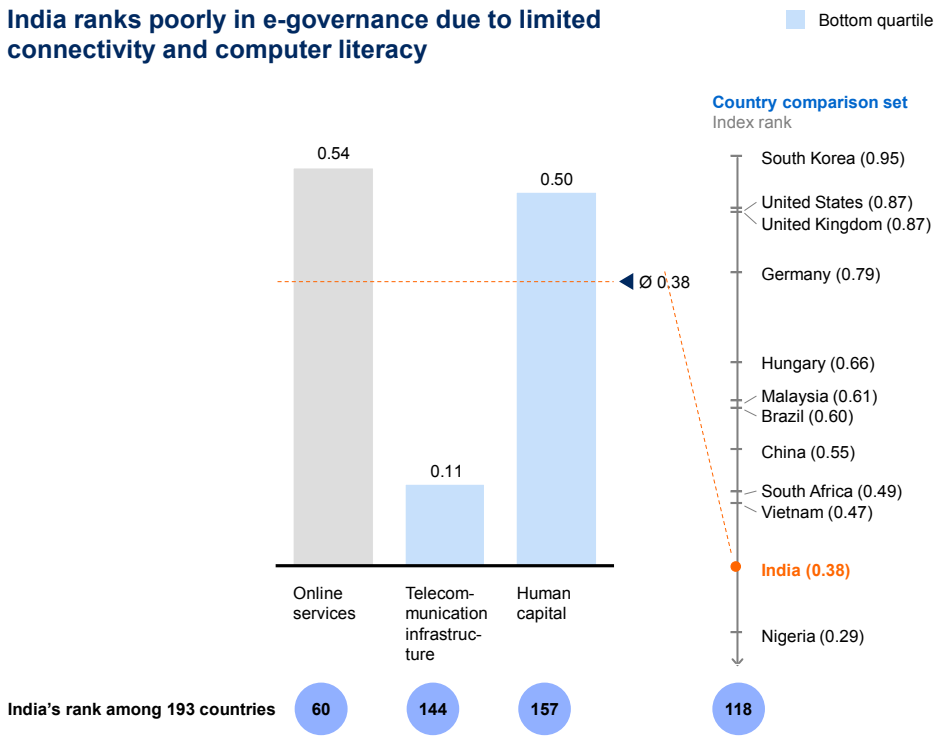
To accelerate progress in e-government initiatives, India will need to invest in additional capabilities. To generate the benefits that e-government can provide across the economy, India will also need to find ways to raise engagement and participation by citizens.

Boosting citizen engagement by making e-government easy to use

India's success in e-government is limited compared with that of many other countries. India ranked 125th out of 193 countries in the United Nations' e-government rankings of 2014—better than Nigeria, Pakistan, and Bangladesh, but much lower than Vietnam, South Africa, the Philippines, and Indonesia. India has a good range of services—ranking 60th out of 193 countries for breadth of e-government offerings—but fares poorly in ease of access, due to poor telecommunications infrastructure and limited "human capital", which measures things such as basic digital literacy (Exhibit 58). These deficiencies have limited citizen participation and have kept India from realising the full benefits of e-government. Many citizens cannot use e-government services because they lack connectivity and computer literacy, or when they can connect, they do not yet find applications that command their attention or are intuitive and easy to use.

Exhibit 58

India ranks poorly in e-governance due to limited connectivity and computer literacy



SOURCE: *E-government survey 2014: Government for the people*, United Nations, June 2104; McKinsey Global Institute analysis

Internet access in India is spreading mostly through mobile devices, so e-government services will be widely used only if they are mobile. This has prompted the government to launch the Mobile Seva initiative. To further encourage use, the processes behind the mobile apps should be computerised and re-engineered for simplicity. Some e-government services in India that have been made available online are not yet completely computerised or do not actually provide transactional capabilities online.

Greater integration of services can also boost citizen engagement. Rather than allowing each ministry to provide its own online service, government can make doing business easier by consolidating services and standardising the way online processes work. For example, the e-Biz portal, which now provides access to such services as downloadable forms and basic information about business clearances and licences, could become the one-stop portal with a single interface for obtaining all approvals and licences, making payments, and providing online compliance certification. This is not simple to execute and would require integrating a host of back-office systems in different ministries. Easy authentication of customers through widespread use of verifiable digital identities for businesses and micro-entrepreneurs (such as corporate digital identities, Aadhaar, and mobile phone–based digital signatures), will make such integrated services increasingly possible in the future as identity becomes portable across regions and jurisdictions.

Building execution capabilities to deliver e-government programmes

To harness the full potential of e-government, India can strengthen its execution capabilities. Global experience shows that successful implementation of complex e-government projects requires strong, high-level coordination across initiatives in different ministries through a strong chief information officer (CIO); explicit commitment to goals and accountability; and milestone-driven execution plans managed with detailed reviews.

To guide their e-government efforts, several countries have appointed a national CIO. The e-government laws enacted in the United States, the United Kingdom, and Austria explicitly call for a centralised coordinator or CIO. In Germany, an IT executive with more than 30 years of private-sector experience was named CIO of the Federal Employment Agency, a sprawling bureaucracy that provides unemployment insurance, job training, and other job-related services. The CIO focused on creating a centralised project-management function to provide training and establish execution guidelines for critical projects. The 90,000-employee agency—Germany's largest—now scores highly on metrics such as cost per user and IT infrastructure integrity.[115]

India's decentralised approach to government IT implementation would demand not one CIO, but many, in state governments and individual ministries and departments. The government's efforts to build the IT skills of its agencies and departments can be strengthened through CIO appointments in each organisation. Singapore's central e-government agency assigns CIOs to government ministries to ensure consistency of e-government applications.

In e-government and other public-sector initiatives, explicit and well-publicised commitments to goals can help raise the pressure to perform. Setting public targets that are backed by political leaders and are crafted with public input tends to keep projects on track. Singapore's iGov2010 report publicly committed the government to attain 90 percent public satisfaction with e-government by 2010.[116] In a 2010 survey, 87 percent of respondents said they were satisfied with the quality of e-government services.[117] In Estonia, the government has committed to

115 *Transforming IT: A German success story*, McKinsey on Government, autumn 2011.

116 *From Integrating Services to Integrating Government*, iGov2010 Masterplan (2006–2010).

117 *E-Government Master Plan 2011–2015*, Info-communications Development Authority of Singapore.

putting all cabinet decisions online within 15 minutes of when they are made. The United States mandates an annual report on the progress of e-government by the Office of Management and Budget. Canada uses regular online surveys and focus groups to gather public feedback.

Finally, a milestone-based delivery approach can maintain the momentum needed to complete projects on time. This requires concentrated focus on defining execution steps, assigning accountability for results (while empowering the implementation team), tracking progress, and resolving bottlenecks. For example, in Germany's Federal Employment Agency initiative, every project had a steering committee and a project manager, who was accountable for meeting project milestones and staying within scope and budget. The manager also was empowered to make the necessary decisions to achieve the outcomes set by the steering committee.

India's government has the opportunity to bring renewed urgency and energy to its e-government programme. Visible sponsorship by top leadership, and strong institutional structures (such as CIO offices at the centre, state, and agency levels), as well as greater focus on encouraging citizens to demand e-government services, can transform the nation's IT capabilities.

□ □ □

India has made a start in launching e-government services that can improve the effectiveness of public programmes, help launch new kinds of businesses, and enable a range of empowering technology applications. The execution of the e-government plan can be improved and the level of engagement with citizens can be raised, and both of these steps are urgent imperatives to harness the potential of technology for India. The multiplier effect of e-government makes this an area that can help, or hinder, the technological progress and adoption in most other sectors.

9. Creating conditions for technologies to flourish

Successful adoption of the 12 disruptive technologies can help India move towards the goals of rapid economic growth, greater social inclusion, and better governance by 2025. For these technologies to take root and have the level of impact we describe in the preceding chapters, India needs to create a supportive environment and provide investments in R&D, human capital, and infrastructure. India can use policy, regulation, and standards to support technology adoption and take steps to encourage a culture of innovation. It can open up government data sets to spark new products, services, and business models. In this chapter, we discuss a range of broad-based enablers that the government could put in place to ensure that the benefits of empowering technologies can be felt across India.

BUILDING PHYSICAL INFRASTRUCTURE FOR THE DIGITAL ECONOMY

The digital technologies we highlight require physical infrastructure to support them. The cloud, the mobile Internet, the Internet of Things, digital payments, and other digital technologies cannot deliver value for India's economy and people without a reliable and affordable infrastructure, including a plentiful and reliable supply of electricity. Today, India's inadequate fibre backbone network leads to poor quality data services and inconsistency of coverage, holding back the spread of the mobile Internet in semiurban and rural parts of the country (Exhibit 59). The cost of Internet access remains beyond the reach of many millions of Indians.

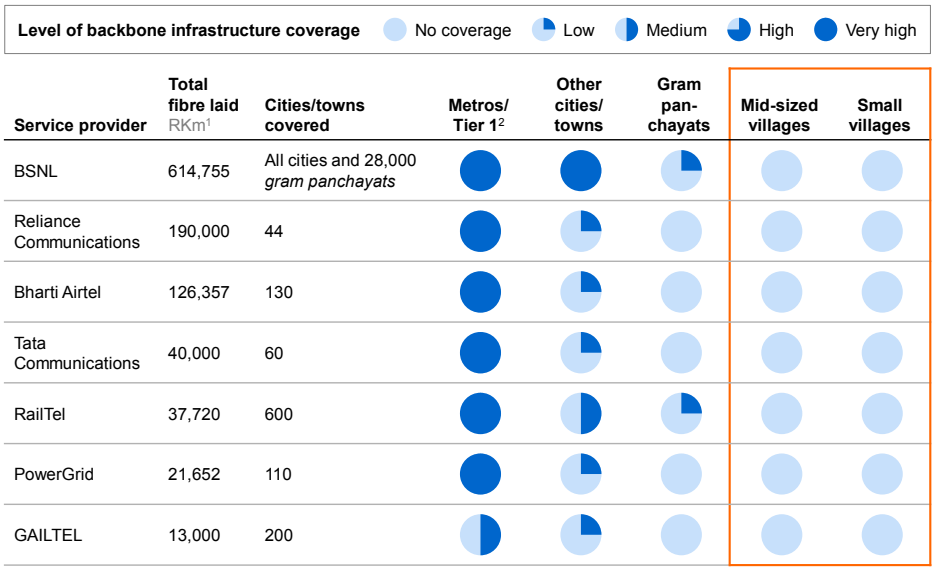
For Indian businesses and citizens to compete and thrive in a modern global economy, universal, affordable Internet access will need to become a public utility that the government provides, in the same way that it provides electricity, clean water, and sanitation. The government is taking steps in this direction. It established the Bharat Broadband Network to extend fibre backbones to 250,000 villages and ensure last-mile connectivity across the nation. As of December 2013, it had reached 40 development blocks, covering 800 villages. Accelerated implementation of the optical fibre backbone will be critical to improving the pace of Internet adoption in rural India. To address affordability of mobile Internet service, India could review its spectrum pricing and allocation policies and take into account the massive growth in data traffic expected in the future when awarding spectrum contracts.

To expand private cloud capacity, providers will need space for new data centres. This can be facilitated by planning and zoning measures to encourage development of low-cost real estate with sufficient power and telecom access. Similar measures, coupled with a renewed thrust in government programs to promote electronics manufacturing, could spur local manufacturing of low-cost mobile handsets and other devices.

Exhibit 59

Lack of fibre infrastructure in rural areas is one of the key reasons for poor broadband penetration

Fibre coverage overview



Service provider	Total fibre laid RKm[1]	Cities/towns covered	Metros/ Tier 1[2]	Other cities/ towns	Gram pan-chayats	Mid-sized villages	Small villages
BSNL	614,755	All cities and 28,000 *gram panchayats*					
Reliance Communications	190,000	44					
Bharti Airtel	126,357	130					
Tata Communications	40,000	60					
RailTel	37,720	600					
PowerGrid	21,652	110					
GAILTEL	13,000	200					

1 Route kilometre is a measure of fibre optic cable length.
2 Cities with populations of more than four million.
SOURCE: Analysys Mason, 2012; McKinsey Global Institute analysis

ADDRESSING DEMAND-SIDE BARRIERS TO TECHNOLOGY ADOPTION

An analysis of Internet barriers in India as well as 24 other developed and developing economies indicates that India scores in the bottom quartile not just on infrastructure but also on capability.[118] Lack of digital literacy is a significant barrier in India, and addressing this is essential for raising adoption. According to a survey by market researcher IMRB, while 48 percent of urban Indians are computer literate, just 14 percent of rural Indians are. India also has one of the most linguistically diverse populations in the world, and the same survey shows that 42 percent of rural Indians prefer accessing the Internet in local languages. The need to tailor devices and services by language makes it more expensive to develop content. Today, many Indian consumers compose written communications using English script instead of their local language script.

Technology-based services will need content in the right languages as well as interfaces that are appropriate for citizens with less formal education and limited experience with computers. The services have to be presented in an easy-to-use and intuitive way. Today, the dominant use of the Internet in rural India is entertainment; the challenge in e-government is to offer services and applications that are as easy to use and intuitive as online entertainment. Interactive video-based content in multiple languages, for example, could show how to navigate websites and could raise participation.

118 *Offline and falling behind: Barriers to Internet adoption*, McKinsey Telecom, Media, and High Tech Practice, 2014.

To reach the least educated and most computer-illiterate segments, India could consider using human intermediaries—or "para-technology" workers. Historically, the postman was the primary interface between illiterate rural citizens and the outside world, writing letters on their behalf, reading them incoming mail, and filling out government forms. In the India of the future, a moderately skilled para-technician (someone with basic education and mobile Internet skills) could fulfil a similar role in connecting poor rural Indians to e-government and other services.

Barriers also exist within user organisations. Across industry and government sectors, there is a shortage of leaders and staff who can conceptualise projects and execute technology-enabled transformations of processes and entire organisations. To build these capabilities across India, it would help to have dedicated technical organisations and groups focused on training and capacity building for specific industries and economic sectors. The financial services industry set up the Institute for Development and Research in Banking Technology in 1996 to develop banking technology. Other sectors could follow this example.

PROVIDING EFFECTIVE POLICIES, REGULATIONS, AND STANDARDS

For empowering technologies to flourish in India, companies and consumers need a clear and predictable legal and regulatory environment. Policy should be technology-agnostic and flexible, allowing businesses to innovate within a clear regulatory framework.

India's government also needs to weigh trade-offs between the benefits that information technologies bring and the risks to privacy and personal security. Government can also consider the unintended consequences of new technologies, such as environmental damage and risks to public health, and think of ways to address concerns about privacy, security breaches, and cyber- or bioterrorism. For example, sensors imbedded in smartphones and cars can provide navigation assistance and location-based services, such as offering instant coupons based on where the consumer is standing in a store. But the ability to track the consumer's location also means that a record can be created of where people go, what they do, and with whom they interact. India's government and people will need to develop consensus about how to balance the benefits and risks of these capabilities. Collaboration between government and the private sector can help create safeguards against criminals and hackers. Any safeguards will need to be updated continuously.

Uniformly accepted standards will be needed to ensure the interoperability of systems and devices, which can help expand the size of the market and encourage greater innovation. The government might consider starting by mandating interoperable standards across its own e-government services. The government can also shape regulations that enable citizens to use various forms of secure credentials—such as smart identity cards or digital certificates on cellphones—that are offered to customers by service providers to make transactions secure. Around the world, efforts are under way to ensure that these credentials are issued and recognised in a standard and interoperable way. Uniform standards for sensors, controllers, and other Internet of Things devices in vehicles could facilitate the rapid adoption of intelligent transportation and logistics systems and improve efficiency in ports, airports, tollways, and electric grids. Standards for tracking technology could also help reduce the scourge of

counterfeit drugs. Creating standards for low-cost medical devices in cooperation with other middle- and low-income countries could accelerate development of these products and bring the benefits to more people sooner.

Finally, government can lead by example by facilitating use of technologies in combinations, which can create greater value than using them in isolation. For example, the great potential benefits of precision farming depend on bringing together advanced GIS and big data analytics. This would require collaboration among owners of the needed data—the Department of Space, which creates GIS data, and the Ministries of Planning, Agriculture, and Water, which have critical data on soil conditions, water supplies, and other factors needed to guide precision farming. Leaders can emphasise the need for collaboration across ministries and departments, and can make sure that organisational issues do not get in the way. New combinations of technologies may necessitate updates to regulations, which will also require a broad and high-level understanding of evolving technologies among regulators in different areas.

CREATING A VIBRANT INNOVATION ECOSYSTEM AND A MINDSET OF "GOING FOR SCALE"

India can create a much better environment for innovation. India ranks 48th in a sample of 61 countries on McKinsey's "ease of Internet entrepreneurship" index, on par with Brazil and Vietnam, but behind China, South Africa, and Malaysia. India scores particularly poorly on the ease of starting a new business and on Internet access (Exhibit 60).[119]

There are good global models for creating a better environment for innovation. Colombia created a one-stop shop and a central business registration database, reducing the time needed to set up a new business from 57 days to three days, on average; the annual rate of new business registrations climbed 70 percent in five years.[120] In Latvia, many businesses complained about overbearing inspections by regulators—often with the implied object of soliciting bribes, the business owners said.[121] The government took steps to standardise inspection procedures and publicised the companies' rights regarding inspection as well as the appeals process for unwarranted violations. Inspections fell by 20 percent in two years, and the probability of being fined for a violation fell by some 80 percent.

Beyond creating a generally business-friendly environment, governments can encourage startups by publicising issues that need to be solved, indicating possible economic impact and other factors that would help companies develop plans. Prize competitions also can spur creative ideas. Grand Challenges Canada, for example, was funded by the government and works with partners such as the Bill and Melinda Gates Foundation on competitions to address challenges in areas such as health care. The XPrize Foundation runs a continuing series of

119 The ease of Internet entrepreneurship index components are: ease of starting a new business (industry-agnostic view of the overall business ecosystem in a country); ease of financing a new business (availability and attractiveness of financing for ICT startups, as well as the cost of financing a new business); and Internet accessibility (extent and cost of Internet access for both enterprises and their target consumers).

120 *How many stops in a one-stop shop? A review of recent developments in business registration*, World Bank Group, December 2009.

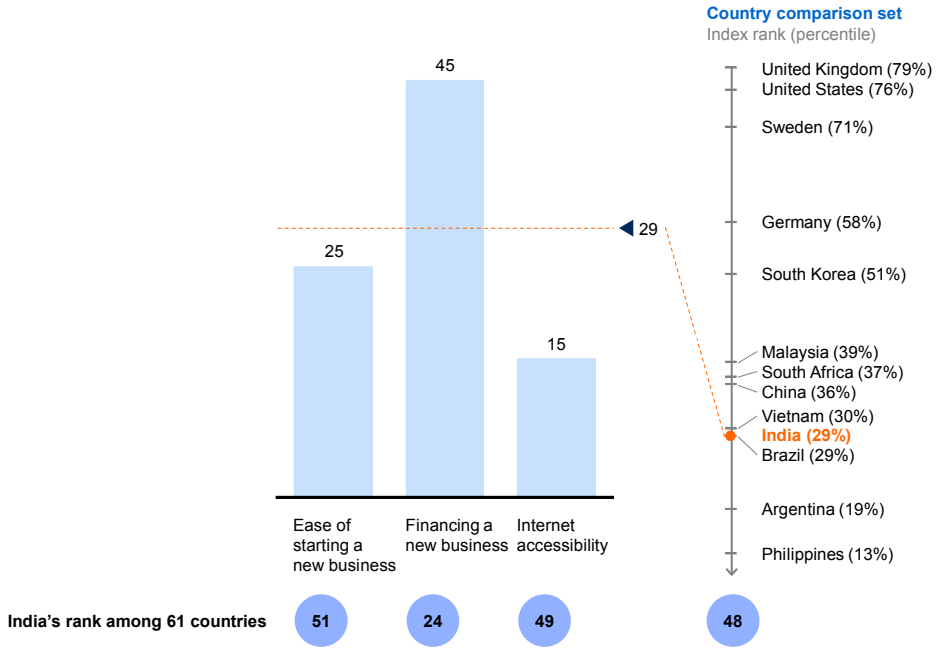
121 Jacqueline Coolidge, Lars Grava, and Sanda Putnina, *Case study: Inspectorate reform in Latvia 1999–2003*, World Bank Group, 2003.

contests in which teams must achieve a specific goal for a monetary prize. For example, it is running the Qualcomm Tricorder Xprize contest, a competition with $10 million in prizes for developers of precision personal diagnostic technologies. In India, Mahindra Spark the Rise offers a $1 million prize to spur innovation.

Grand challenges are good for uncovering ideas, but innovators also need to be able to scale up concepts into large-scale businesses. For entrepreneurs to convert innovative ideas into products and services that have large-scale impact, they will also need innovative business models. As noted earlier, India's mobile telecom market took off rapidly when the regulatory, pricing, and distribution models were developed. To help the next crop of innovators build major businesses, the government can provide some "scale up" funding for companies that have a proven, viable business but would need additional capital to move from a few million customers to tens of millions. Part of the government's new startup fund might be dedicated to fast-growing, established companies as well as startups. These companies could also benefit from a programme to tap the expertise of successful entrepreneurs as "angel consultants" to mentor them and link them with potential partner companies.

Exhibit 60

India's Internet entrepreneurship score reflects challenges in the business environment and Internet access



SOURCE: *E-government survey 2014: Government for the people*, United Nations, June 2014; McKinsey Global Institute analysis

FOSTERING MORE OPENNESS AND TRANSPARENCY IN GOVERNMENT

Around the world, governments are opening up data sets for use by the public and industry. Open data can enable all sorts of applications, innovations, and new business models.[122] These range from the simple smartphone app that tells a commuter when the next bus is arriving by compiling transit and traffic data, to big data analytics that can take public demographic data and proprietary marketing data to discover new and lucrative segments in consumer markets.

A government open data portal that India launched in 2013 now provides access to more than 7,900 data sets. The World Wide Web Foundation's Open Data Index (which rates governments on ten indicators of openness based on access to ten data sets), however, ranked India 63 out of 70 countries on data openness, citing a lack of machine-readable records and limited availability of timely data in bulk (Exhibit 61). To improve its standing and realise the social and economic benefits of open data, India's government could get more departments and agencies to open up their data and prioritise data sets that have the greatest potential value to citizens and business. Mandating release of open data, providing incentives to agencies that contribute open data, and building support among government employees for open data can also help. To encourage innovation based on open data, the government can work directly with app developers and industry associations. For example, India could designate a single national coordinating agency for GIS data, to serve as an ecosystem of GIS app developers.

Exhibit 61

India has taken initial steps to create open databases but needs to make them more user-friendly

Data set	Score %	Do data exist?	In digital form?	Publicly available?	Machine readable?	Available in bulk?	Up to date?
Transport time tables	15	Yes	Yes	Yes	Not sure	No	No
Government budget	25	Yes	Yes	Yes	No	Yes	No
Government spending	15	Yes	Yes	Yes	No	No	No
Election results	35	Yes	Yes	Yes	No	No	Not sure
Company register	15	Yes	Yes	Yes	No	Not sure	No
National maps	15	Yes	Yes	Yes	No	Not sure	No
National statistics	35	Yes	Yes	Yes	No	Yes	Yes
Legislation	25	Yes	Yes	Yes	No	Yes	No
Post codes/Zip codes	0	Not sure	Not sure	Not sure	No	Not sure	Not sure
Emissions of pollutants	35	Yes	Yes	Yes	No	No	No

SOURCE: Open Data Index; Open Knowledge Foundation; McKinsey Global Institute analysis

122 See *Open data: Unlocking innovation and performance with liquid information*, McKinsey Global Institute, October 2013.

Timely and useful content from the government also builds citizen engagement. During its recent economic crisis, Malaysia created the Rangsangan Ekonomi Malaysia website to share information about the government's response. The site made the government's programme transparent and understandable by detailing stimulus spending plans with graphs and downloadable data files. Governments can also encourage participation with incentives: Estonia offered a 30 percent discount on public transportation to people who registered for an electronic identity card. To build engagement in Indonesia, the government launched the Public Participation Information System, which allowed citizens to monitor and verify the delivery of government services in real time, via a website or using SMS texts. The government uses the same data to improve resource allocation and respond quickly when a small footbridge—a minor piece of infrastructure but a major need for the community that depends on it—collapses. The government can even determine which mobile phone users who have registered on the site are close enough to investigate a breakdown in public services, such as uncleared garbage, and ask for their assistance.

ATTRACTING PRIVATE-SECTOR R&D INVESTMENT

India spent just 0.87 percent of GDP on research and development in 2010, focused mainly on defence, agriculture, and health, with smaller shares going to energy, infrastructure, and geographical sciences. India's R&D spending was significantly lower than in Brazil (1.19 percent), China (1.70 percent), the United Kingdom (1.87 percent), the United States (2.79 percent), and South Korea (3.36 percent).[123]

Global R&D activity is shifting towards Asia, mostly to East Asia today (Exhibit 62). In 2011, almost 32 percent of global R&D spending (in purchasing power parity terms) was in East Asia and Southeast Asia, nearly equal to the US share and more than that of the European Union nations. China has led this growth, with R&D spending growing from 2.2 percent of the global total in 2002 to 14.5 percent in 2011.

India can attract more R&D investment and resources from global corporations and the private sector. Non-government R&D spending in 2010 represented about 28 percent of the total in India, compared with 70 percent in the United States. To move towards the US level, India will need to demonstrate that its markets are open, that doing business is easy, and that intellectual property will be protected. To guide R&D investment to high-priority areas, the government could consider establishing a public-private development fund for core technologies in infrastructure, energy, biotechnology, advanced genomics, and other fields.

To strengthen its research institutions, India can clear the path for greater foreign participation in higher education. Academic institutions can be encouraged to build technology incubators, entrepreneurship labs, and technology transfer capabilities through collaboration with industry, technology companies, venture capitalists, and national and international research organisations. In the energy sector, the government can help fill gaps in know-how by supporting a dedicated agency to work with the private sector to build expertise in areas such as data analytics. Centres of excellence in solar R&D and renewable-energy management could be established through public-private partnerships.

123 UNESCO source data cited by the Ministry of Science and Technology.

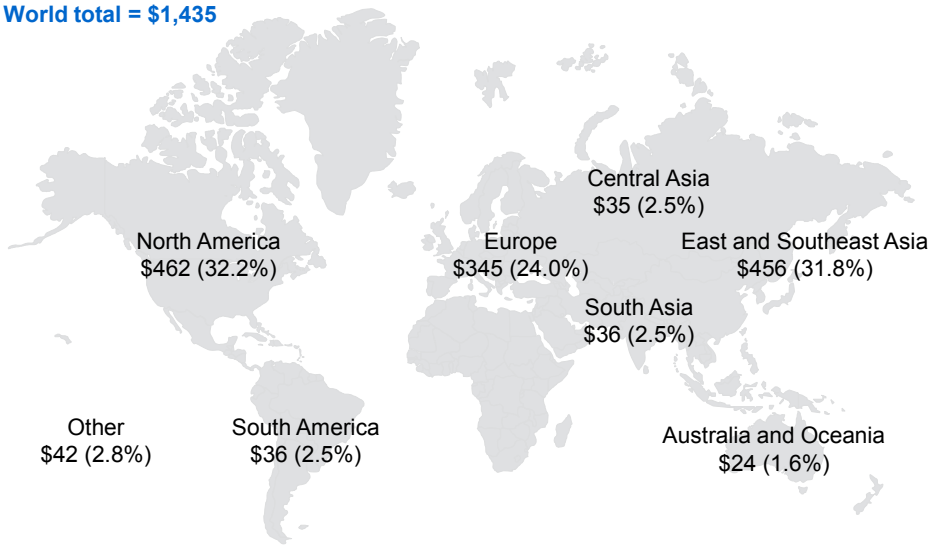
Exhibit 62

East Asia has become a major centre of global R&D activity

Global R&D expenditures, by region, 2011

$ billion, purchasing power parity

World total = $1,435



NOTE: Foreign currencies are converted to U.S. dollars through purchasing power parity, Some country figures are estimated. Countries are grouped according to the regions described by the CIA's *World factbook*. Numbers may not sum due to rounding.

SOURCE: National Science Foundation; National Center for Science and Engineering Statistics estimates, August 2013; Main Science and Technology Indicators (2013/1), OECD; UNESCO; CIA *World factbook*; McKinsey Global Institute analysis

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Adopting the 12 technologies described in this paper across the Indian economy will take continuous effort by many people over many years. We have used a one-decade time horizon because that is a reasonable period in which to make estimates based on current trends. In reality, these technologies will continue to evolve after 2025, and between now and then other technologies with disruptive potential may emerge. The effort to implement the technology applications in this research will require policy makers, educators, medical professionals, small business owners, farmers, and ordinary citizens to master new ways of doing things and new ways of thinking. If they succeed, India will gain more than the economic and social benefits we identify: it will become a nation that is capable of adapting and innovating on a massive scale, with the know-how to compete in global markets and tackle its social challenges.

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